FOR THE NEW EXAMINATIONS

NICHOLLS'S CONCISE GUIDE FOR MATES AND MASTERS

Digitized by the Internet Archive
in 2022 with funding from
Kahle/Austin Foundation

https://archive.org/details/nichollssconcise0002fwma

NICHOLLS'S CONCISE GUIDE.

NICHOLLS'S CONCISE GUIDE

TO THE LOCAL MARINE BOARD EXAMINATIONS

FOR

MATES AND MASTERS

FOR

1929

VOLUME II.

By F. W. MAXWELL, Extra Master

Teacher of Navigation

4th EDITION

ENTERED AT STATIONERS' HALL

GLASGOW

BROWN, SON & FERGUSON, Ltd., Nautical Publishers

52 to 58 Darnley Street

1929

DATES OF EDITIONS.

1*st Edition*, - - - - - *March*, 1925.
2*nd Edition*, - - - - - *August*, 1925.
3*rd Edition*, - - - - - *June*, 1926.
4*th Edition*, - - - - - *February*, 1929.

Printed and Bound in Great Britain
By Brown, Son & Ferguson, Ltd., Glasgow.

PREFACE.

It has been found necessary, on account of the increased amount of work to be done and the greater detail now required at the examinations, to publish *Nicholls's Guide* in two parts, Vol. I. for Second Mates and Vol. II. for Mates and Masters. If the two were bound together, the book would cost practically the same as the two volumes bought separately, and would be inconvenient for use on account of its large bulk and weight. The area of the pages have also been increased to allow for the better setting out of the work.

The author would like to have included the "Reduction to Soundings" and some of the elementary trigonometry in this volume, but found it impracticable, as it would involve a large increase in the size of the book. Those subjects are fully dealt with in Vol. I.

The Marcq Saint Hilaire method of finding a ship's position, also Great Circle Sailing, have been very carefully and fully explained. It is hoped that they have been made clear. They will not be given at the examinations during 1925, but will come in after 1st January, 1926.

Mates and Masters will find that this volume contains a full explanation of the mates and master's work, no time, trouble, or expense having been spared in its preparation; it does **not**, however, contain the second mate's work.

Some of the worked examples of the problems have been worked to the nearest first decimal part of a minute of arc, and some have been worked to seconds. When **time** is being used, **it must always be worked to seconds.** Working to the nearest first decimal part of a minute of arc is quite good enough for all ordinary purposes, and is all that is required at the examinations. Altitudes, however, are sometimes given to seconds, and in problems where such is the case, the answers given at the end of this book have been obtained by working to seconds. If you have worked to the nearest first decimal part of a minute, you should get approximately the same result.

In some examples observed altitudes are given to decimal parts of minutes which are not multiples of 10″. The author has heard men say "**that** altitude could not have been observed, because a sextant can only be read to the nearest 10″ of arc." That is quite true if the sextant is cut to 10″, but many of the best Admiralty pattern sextants are cut to 12″, and when using these instruments, observed altitudes can be read to 12″, 24″, 36″, or 48″—that is, to ·2′, ·4′, ·6′, or ·8′. Any index error on these sextants might be expressed in seconds, such as 48″ or 1′ 24″, or their equivalent in minutes and decimal parts of a minute, which would be (in this case) 0·8′ or 1·4′.

It is easy to make mistakes in many of the small corrections which are necessary, particularly when working the meridian altitude of the moon. Pay special attention to these small matters. For example, when applying the augmentation of the moon's semi-diameter or the reduction of the moon's horizontal parallax, do not write down ·5′ as representing 3″ (·05′ is the correct value). If you get muddled with these little things, try a different way. Multiply the decimal figure of your semi-diameter and horizontal parallax by 6 to reduce it to seconds when you copy it down from the *Nautical Almanac*. Correct it for the Greenwich time and then apply your augmentation and reduction, respectively, in seconds. If desired, you can divide the resulting seconds by 6 to bring them back to decimal parts of a minute, or you can correct your altitude to seconds, carrying on with seconds throughout.

Double Altitude (Position lines) Problem.

In the Sumner and Marcq St. Hilaire methods the figures are drawn for approximate latitudes, the exact latitude not being known at the time of drawing them. In no case would the difference between the approximate and correct latitude be large enough to make any material difference to the figure. Also, one circle of declination is drawn for the same object at two different observations, though in the case of the sun the declination may have undergone a little change in the interval. The run between the time of taking the two observations is not shown in the astronomical figure, but, of course, appears when the problem is projected on the chart.

The calculations in all the problems have been carefully checked, but it is likely that a few errors will be found in so large a number of figures. The author will be very glad if candidates will let him know should any be discovered. He will also be thankful for suggestions for improvement in future editions.

He also wishes to acknowledge the very valuable help and co-operation which he has received from Capt. H. T. Jefferys and Capt. C. A. Vickery throughout the preparation of the work. It has proved to be more than a " one-man job."

F. W. MAXWELL.

LONDON, *March*, 1925.

PREFACE TO THE FOURTH EDITION.

THE abridged edition of the 1929 *Nautical Almanac* now being in use at the examinations, it has become necessary to bring out a new edition of this book.

Previous to the year 1925, the astronomical day began at noon, 12 hours later than the corresponding civil day, and ended at the following noon ; but for the year 1925 and later years the day begins at midnight and ends at the following midnight.

This change of 12 hours in the expression of time involved the addition or subtraction of 12 hours at some stage or other in the working of nearly all astronomical problems.

That addition or subtraction of 12 hours is now done for us in *The Nautical Almanac* by the tabulation of two new quantities called " R." and " E."

R. is the R.A.M.S. + 12 hrs. (12 hrs. being rejected when the sum exceeds 24 hrs.).

E. is 12 hours — Equation of time.

By using these two quantities instead of the actual value of the R.A.M.S. and equation of time respectively, the addition or subtraction of this 12 hrs. in the problems is avoided.

Another advantage is that E. (also R.) is always applied the same way in any one particular problem, consequently no more failures caused by applying the Equation of time the wrong way. The introduction of these two new quantities must, therefore, be considered an improvement.

Note also, that the Right Ascension and Declination of the planets, which were formerly given for Greenwich mean noon, are now, together with their meridian passage, given for midnight (0h.) on every day.

Up to the present time the planets have not been included in the problems set at the ordinary examinations. It is probable, however, that they will come in before long. The planet problems have, therefore, been brought up to date, and a new sun and planet double altitude inserted in Exam. Paper IV.

The haversine formula is now used to find the courses as well as the distance in Great Circle Sailing.

A table of PROPORTIONAL PARTS to be added in interpolating R. is given with this book.

Again Capt. Jefferys has given me valuable assistance in preparing this edition, which, on account of short notice of change of Almanac, has involved long hours of work. I tender him my sincere thanks.

F. W. MAXWELL.

January, 1929.

CONTENTS.

PART I.

CONTAINING THE WORK REQUIRED FOR FIRST MATES.

	PAGE
Plane Trigonometry,	1
Right-angled Spherical Trigonometry,	47
Solution of Quadrantal Spherical Triangles,	51
Latitude by Meridian Altitude of a Star,	79
Longitude by Chronometer by Altitude of a Star,	91
To Find the R.A.M.,	98
Stars near the Meridian,	101
Star Time Azimuth,	109
Reduction to the Meridian (Sun and Star),	116
Time when a Star is on the Meridian,	129
Double Altitude (Position Lines)—Sumner's Method,	138
Double Altitude (Position Lines)—Marcq St. Hilaire Method,	150
Questions and Answers relating to Stars and Planets,	167
Laws of Storms,	168
Meteorology,	173
Freight and Commission,	185
Capacities of Holds, Bunkers, and Tanks,	188
Questions on the use of the Hydrometer,	191
Chartwork	193
Reduction to Soundings,	219

PART II.

CONTAINING THE WORK REQUIRED FOR MASTERS.

PAGE

Latitude by the Pole Star, ... 266

Latitude by Meridian Altitude of the Moon, ... 272

Napier's Diagram, ... 279

Great Circle Sailing, ... 288

Composite Great Circle Sailing, ... 296

The Planets, ... 302

Essays, ... 316

Coal Consumption 326

Deviation Questions and Answers, ... 331

The Gyro Compass, ... 362

Examination Papers, ... 367

Answers to Problems, ... 383

Answers to Examination Papers, ... 399

Extracts from Nautical Almanac, ... 412

Extracts from Tide Tables, ... 451

CONDUCT OF THE EXAMINATIONS.

The examinations will begin at 10 a.m. on each day. A regular luncheon interval will be given each day between 1 p.m. and 2 p.m., the *viva voce* and practical parts of the examination being taken at such times as may be convenient. The time allotted for each written part of the examination for each grade of certificate will be as follows:—

First or Only Mate.—Paper on Navigation and Nautical Astronomy, 3 hours; Nautical Astronomy and Trigonometry, 2 hours; Chart work, 3 hours; Sumner problem, 2 hours; Meteorology paper, 1½ hours.

Master.—Paper on Navigation and Nautical Astronomy, 3 hours; Nautical Astronomy and Trigonometry, 2 hours; Chart work, 3 hours; Meteorology paper, 1½ hours; Compass Deviation, 1½ hours; Naval Architecture, 1½ hours; Essay, 2 hours.

A two hours paper on a Great Circle problem will be added in some instances, and either the paper on Meteorology or the Essay will be omitted.

LIST OF PRACTICE CHARTS.

The following Charts can be used for working out examples in *Nicholls's Concise Guides*:—

English Channel Chart - - -	Price	1/-
Tasmania Chart - - - -	„	1/-
Kyle Akin Plan Chart - - -	„	9d.
Sumner Chart, 46° to 49° - -	„	9d.
„ „ 49° to 52° - -	„	9d.
St. George's Channel Chart - -	„	9d.
	Post	3d.
		5/3

All Charts are full size and printed on good paper.

These Charts can be had from any Nautical Optician, etc., or from the Publishers:—

BROWN, SON & FERGUSON, LTD.,
52-58 DARNLEY STREET, GLASGOW, S.1.

Very helpful to Candidates preparing for Board of Trade Examinations.

NICHOLLS'S CONCISE GUIDE.

VOL. II.

TRIGONOMETRY.

CANDIDATES for **First Mates'** and **Masters'** certificates are required to have an elementary knowledge of theoretical plane trigonometry, and to be able to solve problems in **plane** and **right-angled spherical** trigonometry.

In order that the student may better grasp the why and wherefore of the subject, a suitable amount of fundamental detail has been included. This should be thoroughly digested before proceeding with the more practical part of the work.

The writer has endeavoured to make the explanations as simple as possible, and hopes that his considerable experience in preparing candidates for the B.O.T. examinations has resulted in his being able to put them in a form in which they will be readily understood.

Take each part of the work slowly, step by step, do not miss the slightest detail, and always bear in mind that the result of your examination, to a great extent, will depend on the soundness of your knowledge of this subject.

Trigonometry is the foundation stone of navigation, and without its knowledge it is impossible to understand the principle of the problems to which you have to supply the answers. It is, therefore, of vital importance to the sailor and officer.

It is necessary that a neat and orderly method of setting the work out should be adopted. To help you in this matter there are given a large number of worked examples ; their general arrangement and form ought to be carefully copied.

Having done all the trigonometry in Vol. I. (*Nicholls's Concise Guide for Second Mates*), Mates and Masters should now carry on with the following identities and problems, doing them in the order in which they are here given. Some of the problems in Vol. I. have been repeated, showing an alternative method of working them.

Worked Examples of Identities.

1. Draw a figure and prove that $\dfrac{1}{\sqrt{1+\tan^2 A}} = \dfrac{1}{\sqrt{1+\dfrac{1}{\operatorname{cosec}^2 A - 1}}}$.

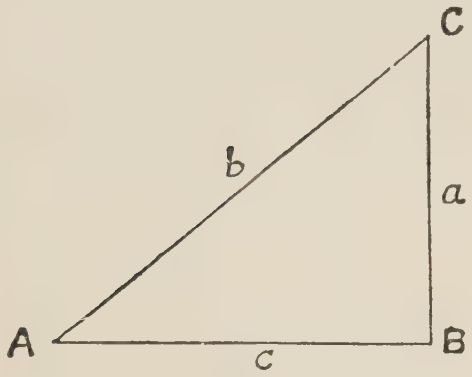


Fig. 1.

In R.A. triangle $A\,B\,C$ $\dfrac{b^2}{a^2} - \dfrac{a^2}{a^2} = \dfrac{c^2}{a^2}$.

i.e., $\operatorname{cosec}^2 A - 1 = \cot^2 A$.

$\therefore$ $\dfrac{1}{\sqrt{1+\tan^2 A}} = \dfrac{1}{\sqrt{1+\dfrac{1}{\cot^2 A}}}$,

hence $\dfrac{1}{\sqrt{1+\tan^2 A}} = \dfrac{1}{\sqrt{1+\tan^2 A}}$.

These two quantities are now identical, and it is not necessary to proceed any further to prove the identity. They may, however, both be brought to simple terms, as follows :—

$$\frac{1}{\sqrt{1+\tan^2 A}} = \frac{1}{\sqrt{1+\tan^2 A}}$$

i.e., $$\frac{1}{\sqrt{\sec^2 A}} = \frac{1}{\sqrt{\sec^2 A}}$$

i.e., $$\frac{1}{\sec A} = \frac{1}{\sec A}$$

hence $$\cos A = \cos A.$$

2. Draw a figure and prove that

$$\frac{1}{(\operatorname{cosec} A + 1)(\operatorname{cosec} A - 1)} = \left(\frac{1}{\cos A} + 1\right)\left(\frac{1}{\cos A} - 1\right)$$

i.e., $$\frac{1}{\operatorname{cosec}^2 A - 1} = \frac{1^2}{\cos^2 A} - 1^2$$

i.e., $$\frac{1}{\operatorname{cosec}^2 A - 1} = \sec^2 A - 1.$$

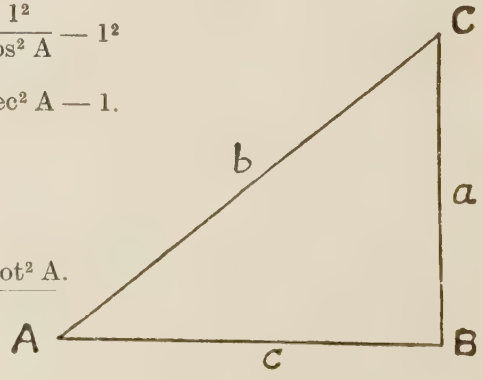
In R.A. triangle $A\,B\,C$,

$\dfrac{b^2}{c^2} - \dfrac{c^2}{c^2} = \dfrac{a^2}{c^2}$. $\qquad$ $\dfrac{b^2}{a^2} - \dfrac{a^2}{a^2} = \dfrac{c^2}{a^2}$.

i.e., $\sec^2 A - 1 = \tan^2 A$, $\qquad$ $\operatorname{cosec}^2 A - 1 = \cot^2 A$.

$\therefore$ $\dfrac{1}{\cot^2 A} = \tan^2 A$.

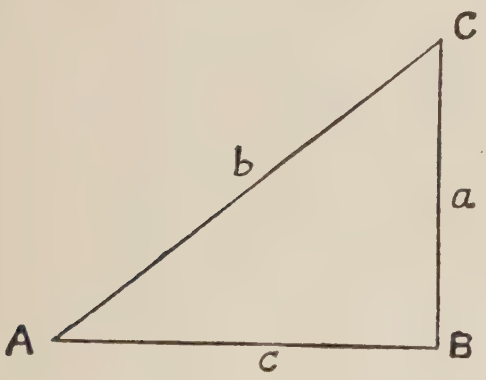
and $\tan^2 A = \tan^2 A$.



We have proved this identity by bringing both sides of the equation to $\tan^2 A$, and it will readily be seen that if both are equal to $\tan^2 A$ they must be equal to each other. Another method of solving this example is to bring the first expression to the identical components of the second expression :—

i.e.,
$$\frac{1}{(\operatorname{cosec} A + 1)(\operatorname{cosec} A -)} = \frac{1}{\operatorname{cosec}^2 A - 1} = \frac{1}{\cot^2 A}$$
$$= \tan^2 A = \sec^2 A - 1$$
$$= \frac{1}{\cos^2 A} - 1 = \frac{1^2}{\cos^2 A} - 1^2$$
$$= \left(\frac{1}{\cos A} + 1\right)\left(\frac{1}{\cos A} - 1\right).$$

3. Draw a diagram and prove that



$$(1 - \tan A)(1 + \tan A)$$
$$= (\sqrt{2} - \sec A)(\sqrt{2} + \sec A).$$
i.e., $1 - \tan^2 A = 2 - \sec^2 A.$

In R.A. triangle $A\,B\,C$, $\frac{a^2}{c^2} = \frac{b^2}{c^2} - \frac{c^2}{c^2}$

i.e., $\tan^2 A = \sec^2 A - 1.$

$\therefore$ $1 - (\sec^2 A - 1) = 2 - \sec^2 A.$

i.e., $1 - \sec^2 + 1 = 2 - \sec^2 A.$

$\therefore$ $2 - \sec^2 A = 2 - \sec^2 A.$

4. Draw a figure and prove that

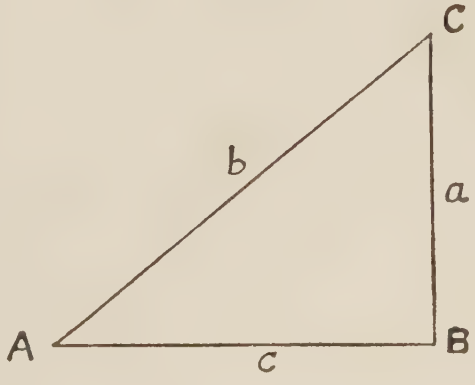
$$(\tan A + 1)^2 = \sec^2 A + 2 \tan A.$$

i.e., $\tan^2 A + 1 + 2 \tan A = \sec^2 A + 2 \tan A.$

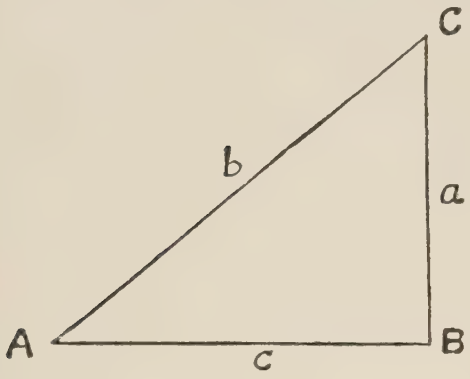
In R.A. triangle $A\,B\,C$, $\frac{a^2}{c^2} + \frac{c^2}{c^2} = \frac{b^2}{c^2}$

i.e., $\tan^2 A + 1 = \sec^2 A.$

$\therefore$ $\sec^2 A + 2 \tan A = \sec^2 A + 2 \tan A.$



5. Draw a diagram and prove that



$$(\cos A - \sin A)^2 = 1 - 2 \cos A \sin A$$

i.e., $\cos^2 A + \sin^2 A - 2 \cos A \sin A$

$$= 1 - 2 \cos A \sin A.$$

In R.A. triangle $A\,B\,C$, $\frac{c^2}{b^2} + \frac{a^2}{b^2} = \frac{b^2}{b^2}$

i.e., $\cos^2 A + \sin^2 A = 1.$

$\therefore$ $1 - 2 \cos A \sin A = 1 - 2 \cos A \sin A$

6. Draw a diagram and prove that

$$\frac{1}{\cot^2 A + 1} = \left(1 - \frac{1}{\sec A}\right)\left(1 + \frac{1}{\sec A}\right)$$

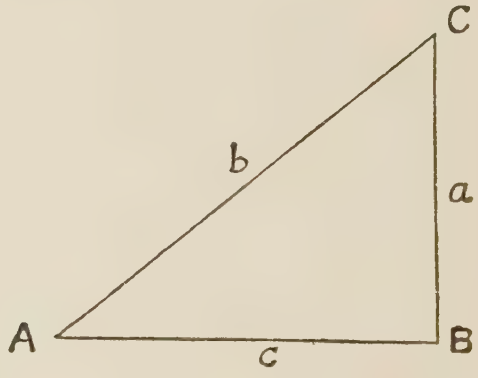
i.e., $$\frac{1}{\cot^2 A + 1} = 1 - \frac{1}{\sec^2 A} = 1 - \cos^2 A.$$

In R.A. triangle $A\,B\,C$, $\frac{c^2}{a^2} + \frac{a^2}{a^2} = \frac{b^2}{a^2}$.

i.e., $\cot^2 A + 1 = \operatorname{cosec}^2 A.$

Also, $\frac{b^2}{b^2} - \frac{c^2}{b^2} = \frac{a^2}{b^2}$.

i.e., $1 - \cos^2 A = \sin^2 A.$



$\therefore$ we have $\frac{1}{\operatorname{cosec}^2 A} = \sin^2 A$

i.e., $\sin^2 A = \sin^2 A.$

To prove that sin $(A + B) =$ sin A, cos $B +$ cos A, sin B, and cos $(A + B) =$ cos A cos $B -$ sin A sin B.

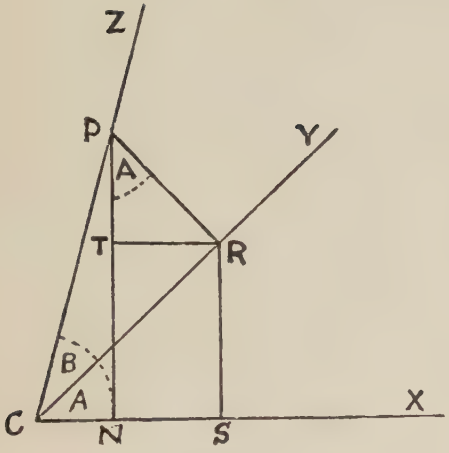


Fig. 2.

Let $Y\,C\,X = A$ and $Z\,C\,Y = B$, then $Z\,C\,X = (A + B)$.

On $C\,Z$ (the line that includes the angle $(A + B)$), take any point P, and from this point drop a perpendicular on $C\,Y$ ($P\,R$), make $P\,N$ and $R\,S$ perpendicular to $C\,X$, and $R\,T$ perpendicular to $P\,N$.

Because $T\,R$ is parallel to $C\,X$, and $C\,Y$ cuts both at the same angle, angle $T\,R\,C = R\,C\,X = A$ (Euc. 1, Prop. 29).

As $T\,P\,R$ and $T\,R\,C$ are both complements of $T\,R\,P$,

$$T\,P\,R = T\,R\,C = A.$$

$$\text{Sin}\,(A + B) = \frac{N\,P}{C\,P} = \frac{N\,T + T\,P}{C\,P} = \frac{S\,R + T\,P}{C\,P}.$$

$$= \frac{S\,R}{C\,P} + \frac{T\,P}{C\,P}.$$

By multiplying $\frac{S\,R}{C\,P}$ by hypotenuse $C\,R$, both numerator and denominator,

and multiplying $\frac{T\,P}{C\,P}$ by hypotenuse $P\,R$, both numerator and denominator, we obtain

$$\sin\,(A + B) = \frac{S\,R \times C\,R}{C\,R \times C\,P} + \frac{T\,P \times P\,R}{P\,R \times C\,P}$$

$$\therefore \quad \underline{\sin\,(A + B) = \sin A, \cos B + \cos A, \sin B.}$$

$$\text{Also,} \quad \cos\,(A + B) = \frac{C\,N}{C\,P} = \frac{C\,S - N\,S}{C\,P} = \frac{C\,S - T\,R}{C\,P}$$

$$= \frac{C\,S}{C\,P} - \frac{T\,R}{C\,P}.$$

Multiplying each fraction by $C\,R$ and $P\,R$ as before, we obtain :—

$$\cos\,(A + B) = \frac{C\,S \times C\,R}{C\,R \times C\,P} - \frac{T\,R \times P\,R}{P\,R \times C\,P};$$

i.e., $\underline{\cos\,(A + B) = \cos A, \cos B - \sin A, \sin B.}$

To prove that $\sin (A - B) = \sin A \cos B - \cos A \sin B$
and $\cos (A - B) = \cos A \cos B + \sin A \sin B$.

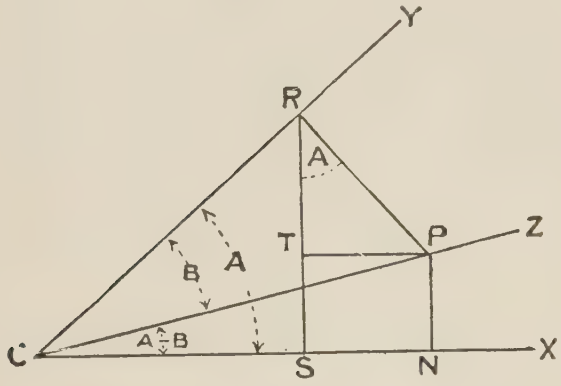


Fig. 3.

Let angle $X\,C\,Y = A$ and angle $Z\,C\,Y = B$, then angle $X\,C\,Z = (A - B)$.

From any point P on $C\,Z$ [the line that includes the angle $(A - B)$] make $P\,R$ perpendicular to $C\,Y$. Make $R\,S$ and $P\,N$ perpendicular to $C\,X$, and $P\,T$ perpendicular to $R\,S$.

Angles $T\,R\,P$ and $X\,C\,R$ are both complements of angle $C\,R\,S$

$\therefore$ angle $T\,R\,P = X\,C\,R = A$.

Now, $$\sin (A - B) = \frac{N\,P}{C\,P} = \frac{S\,R - R\,T}{C\,P}$$

$$= \frac{S\,R}{C\,P} - \frac{R\,T}{C\,P}.$$

By multiplying numerator and denominator of each fraction by the hypotenuse $C\,R$ and $R\,P$ respectively we obtain :—

$$\sin (A - B) = \frac{S\,R \times C\,R}{C\,R \times C\,P} - \frac{R\,T \times R\,P}{R\,P \times C\,P}.$$

$\therefore$ $\underline{\sin (A - B) = \sin A, \cos B - \cos A, \sin B.}$

Also, $$\cos (A - B) = \frac{C\,N}{C\,P} = \frac{C\,S + S\,N}{C\,P} = \frac{C\,S + T\,P}{C\,P}.$$

$$= \frac{C\,S}{C\,P} + \frac{T\,P}{C\,P}.$$

By multiplying numerator and denominator of each fraction by the hypotenuse $C\,R$ and $R\,P$ respectively we obtain :—

$$\cos (A - B) = \frac{C\,S \times C\,R}{C\,R \times C\,P} + \frac{T\,P \times R\,P}{R\,P \times C\,P}.$$

$\therefore$ $\underline{\cos (A - B) = \cos A, \cos B + \sin A, \sin B.}$

Angles of $(90°-A)$ $(90°+A)$ $(180°-A)$ and $(180°+A)$

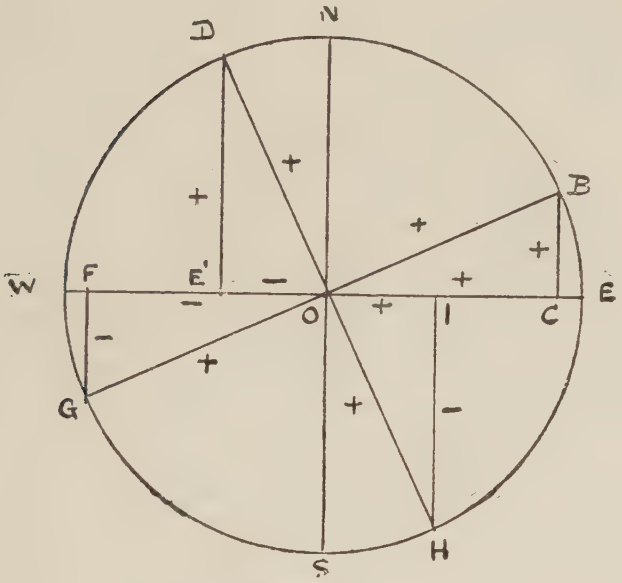


Fig. 1.

To understand these angles the student must be familiar with the conventional signs relating to them.

An easy way for the nautical man to remember them is for him to look upon figure 1 as the earth with $N\,S$ representing the meridian of Greenwich, and $W\,E$ the equator.

Then—

All lines drawn from the equator into North latitude are positive.
All lines drawn from the equator into South latitude are negative.
All lines drawn from the meridian into East longitude are positive.
All lines drawn from the meridian into West longitude are negative.
The radius is always positive.

Therefore $B\,C$ $D\,E^1$ $O\,I$ and $O\,C$ are positive
$F\,G$ $I\,H$ $O\,E^1$ and $O\,F$ are negative
The radii $O\,B$ $O\,D$ $O\,G$ and $O\,H$ are positive

The functions of the angle $(90° - A)$.

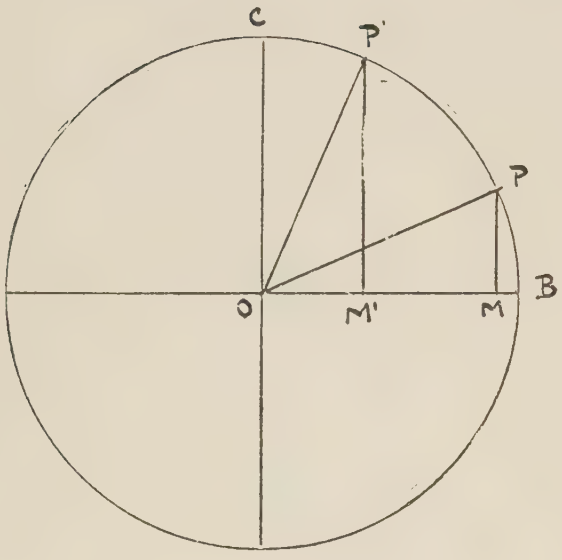


Fig. 2.

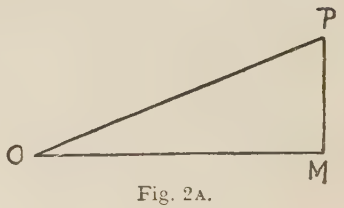


Fig. 2A.

Let the radius $O\ B$ (figure 2) revolve anti-clockwise to the position $O\ P$, making the angle $P\ O\ M = A$

Let the radius revolve to the position $O\ C$ making the angle $B\ O\ C = 90°$

Now let the radius revolve clockwise from $O\ C$ to $O\ P^1$ making the angle $C\ O\ P^1 = A$, then the angle $P^1\ O\ M^1 = (90° - A)$

$P\ M$ and $P^1\ M^1$ are drawn perpendicular to $O\ B$ making the angles $P\ M\ O$ and $P^1\ M^1\ O$ both equal to 90°

The angle	$P\ O\ M$	=	the angle	$O\ P^1\ M^1$
,,	$O\ P\ M$	=	,,	$P^1\ O\ M^1$
,,	$P\ M\ O$	=	,,	$P^1\ M^1\ O = 90°$

The side	$O\ P$	=	the side	$O\ P^1$ = radius
,,	$P\ M$	=	,,	$O\ M^1$
,,	$P^1\ M^1$	=	,,	$O\ M$

The two triangles are therefore equal in every respect.

The functions of the angle $(90°-A)$

To prove $\sin A=\cos(90°-A)$

$$\frac{PM}{OP}=\frac{OM^1}{OP^1}$$ but $PM=OM^1$, and $OP=OP^1$ $\therefore \sin A=\cos(90°-A)$

To prove $\cos A=\sin(90°-A)$

$$\frac{OM}{OP}=\frac{P^1M^1}{OP^1}$$ but $OM=P^1M^1$, and $OP=OP^1$ $\therefore \cos A=\sin(90°-A)$

To prove $\sec A=\operatorname{cosec}(90°-A)$

$$\frac{OP}{OM}=\frac{OP^1}{P^1M^1}$$ but $OP=OP^1$, and $OM=P^1M^1$ $\therefore \sec A=\operatorname{cosec}(90°-A)$

To prove $\operatorname{cosec} A=\sec(90°-A)$

$$\frac{OP}{PM}=\frac{OP^1}{OM^1}$$ but $OP=OP^1$, and $PM=OM^1$ $\therefore \operatorname{cosec} A=\sec(90°-A)$

To prove $\tan A=\cot(90°-A)$

$$\frac{PM}{OM}=\frac{OM^1}{P^1M^1}$$ but $PM=OM^1$, and $OM=P^1M^1$ $\therefore \tan A=\cot(90°-A)$

To prove $\cot A=\tan(90°-A)$

$$\frac{OM}{PM}=\frac{P^1M^1}{OM^1}$$ but $OM=P^1M^1$, and $PM=OM^1$ $\therefore \cot A=\tan(90°-A)$

All the above results can be obtained very easily by the use of the plane triangle OPM (figure 2A).

Let POM be any angle less than 90°. Let a perpendicular fall from P on to OM making the angle $PMO=90°$

Then as the three angles of any plane triangle equal 180°, if we consider the angle POM to equal A, then the angle OPM must equal $90°-A$.

To prove $\sin A=\cos(90°-A)$

$$\frac{PM}{OP}=\frac{PM}{OP}$$ $\therefore \sin A=\cos(90°-A)$ and so on.

The functions of the angle $(90°+A)$

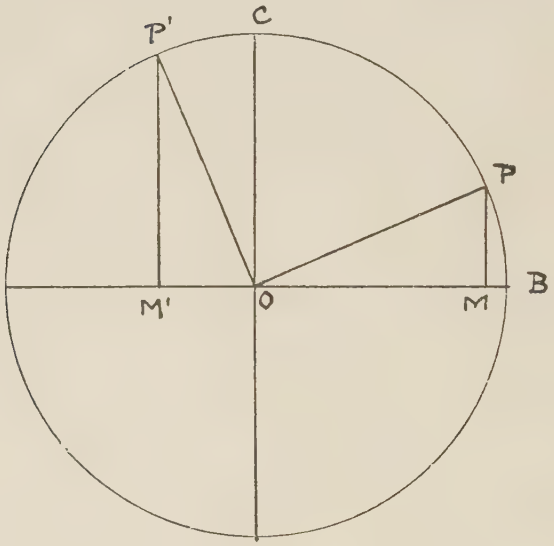


Fig. 3.

Let the radius $O\ B$ (figure 3) revolve anti-clockwise to the position $O\ P$ making the angle $B\ O\ P$ equal to A.

Let the radius turn through a right angle from $O\ P$ to $O\ P^1$ so that the angle $B\ O\ P^1$ is equal to $(90°+A)$.

From P and P^1 draw $P\ M$ and $P^1 M^1$ perpendicular to $B\ O$ produced.

In the figure since $P\ O\ P^1$ is a right angle, the sum of the angles $M\ O\ P$ and $P^1\ O\ M^1$ is also a right angle.

Therefore the angle $M\ O\ P = 90°$ — the angle $P^1\ O\ M^1$ = the angle $O\ P^1\ M^1$

The two triangles $M\ O\ P$ and $M^1\ P^1\ O$ are therefore equal in every respect.

$O\ M$ and $M^1\ P^1$ are numerically equal.

$M\ P$ and $O\ M^1$ are numerically equal.

$O\ P$ and $O\ P^1$ are numerically equal.

In the figure $O\ M$ and $M^1\ P^1$ have the same sign, as also have $O\ P$ and $O\ P^1$, but $M\ P$ and $O\ M^1$ have the opposite sign.

$+M^1\ P^1 = +O\ M$, and $-O\ M^1 = M\ P\ \therefore\ +O\ M^1 = -M\ P$

The functions of the angle $(90°+A)$

To prove $\sin(90°+A)=\cos A$

$$\text{Sin } BOP^1 = \frac{M^1P^1}{OP^1} = \frac{OM}{OP} = \cos A \therefore \sin(90°+A)=\cos A$$

To prove $\cos(90°+A)= -\sin A$

$$\text{Cos } BOP^1 = \frac{OM^1}{OP^1} = \frac{-MP}{OP} = -\sin A \therefore \cos(90°+A)= -\sin A$$

To prove $\tan(90°+A) = -\cot A$

$$\text{Tan } BOP^1 = \frac{M^1P^1}{OM^1} = \frac{OM}{-MP} = -\cot A \therefore \tan(90°+A)= -\cot A$$

To prove $\cot(90°+A)= -\tan A$

$$\text{Cot } BOP^1 = \frac{OM^1}{M^1P^1} = \frac{-MP}{OM} = -\tan A \therefore (90°-A)= -\tan A$$

To prove $\sec(90°+A)= -\operatorname{cosec} A$

$$\text{Sec } BOP^1 = \frac{OP^1}{OM^1} = \frac{OP}{-MP} = -\operatorname{cosec} A \therefore \sec(90°+A)= -\operatorname{cosec} A$$

To prove $\operatorname{cosec}(90°+A)=\sec A$

$$\text{Cosec } BOP^1 = \frac{OP^1}{M^1P^1} = \frac{OP}{OM} = \sec A \therefore \operatorname{cosec}(90°+A)=\sec A$$

To prove $\sin(90°+A)=\sin(90°-A)$

$$\text{Sin } BOP^1 = \frac{M^1P^1}{OP^1} = \sin MPO = \frac{OM}{OP} = \sin(90°-A) \text{ or } \cos A \therefore \sin(90°+A)= \sin(90°-A)$$

The functions of the angle $(180° - A)$

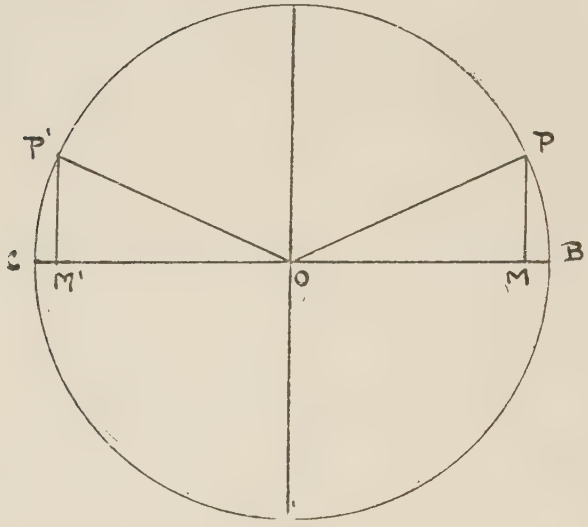


Fig. 4.

In figure 4 let the radius $O\ B$ revolve anti-clockwise to $O\ P$ making the angle $M\ O\ P = A$.

Let it revolve right through 180° from B to C.

Again, let it revolve clockwise through an angle equal to A to position P^1

Then $M^1O\ P^1 = A$ and $M\ O\ P^1 = (180° - A)$.

As explained in the foregoing examples the triangles $P\ O\ M$ and $P^1O\ M^1$ are equal in every respect.

$O\ P$ and $O\ P^1$ are numerically equal.

$P\ M$ and P^1M^1 are numerically equal.

$O\ M$ and $O\ M^1$ are numerically equal.

In the figure $O\ P$ and $O\ P^1$ have the same sign, as also have $P\ M$ and P^1M^1, but $O\ M$ and $O\ M^1$ have the opposite sign.

$+P\ M = +P^1M^1$, and $-\ O\ M^1 = O\ M\ \therefore\ O\ M^1 = -\ O\ M$.

The functions of the angle $(180°-A)$

To prove that $\sin(180°-A)=\sin A$

$$\text{Sin } BOP^1 = \frac{P^1M^1}{OP^1} = \frac{PM}{OP} = \sin A \therefore \sin(180°-A)=\sin A$$

To prove $\cos(180°-A)= -\cos A$

$$\text{Cos } BOP^1 = \frac{OM^1}{OP^1} = \frac{-OM}{OP} = -\cos A \therefore \cos(180°-A)= -\cos A$$

To prove $\tan(180°-A)= -\tan A$

$$\text{Tan } BOP^1 = \frac{P^1M^1}{OM^1} = \frac{PM}{-OM} = -\tan A \therefore \tan(180°-A)= -\tan A$$

To prove $\operatorname{cosec}(180°-A)=\operatorname{cosec} A$

$$\text{Cosec } BOP^1 = \frac{OP^1}{P^1M^1} = \frac{OP}{PM} = \operatorname{cosec} A \therefore \operatorname{cosec}(180°-A)=\operatorname{cosec} A$$

To prove $\sec(180°-A)= -\sec A$

$$\text{Sec } BOP^1 = \frac{OP^1}{OM^1} = \frac{OP}{-OM} = -\sec A \therefore \sec(180°-A)= -\sec A$$

To prove $\cot(180°-A)= -\cot A$

$$\text{Cot } BOP^1 = \frac{OM^1}{P^1M^1} = \frac{-OM}{PM} = -\cot A \therefore \cot(180°-A)= -\cot A$$

The functions of the angle $(180°+A)$

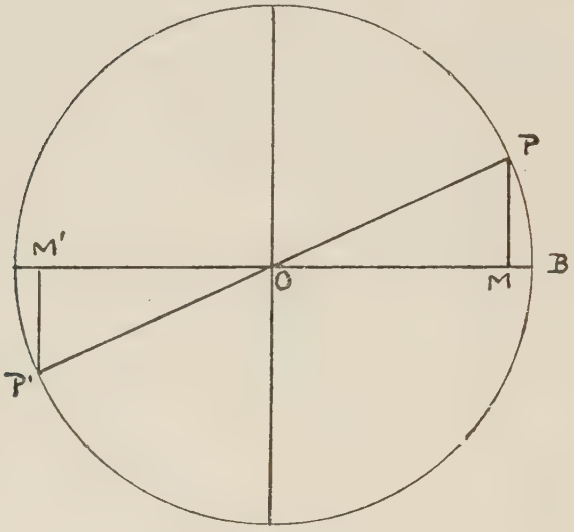


Fig. 5.

In figure 5 let the radius $O\ B$ revolve anti-clockwise to the position $O\ P$ and let the angle $P\ O\ M$ be called A.

Let the radius still revolve through another 180° to the position $O\ P^1$, then the angle $B\ O\ P^1=(180°+A)$.

The angle $P\ O\ M$ equals the angle $M^1O\ P^1$, the angles $O\ M\ P$ and $O\ M^1P^1$ each equal 90°, and the radius $O\ P$ = the radius $O\ P^1$. Therefore in each of the triangles $M\ O\ P$ and $M^1O\ P^1$ we have common angles and sides, and so by Euclid I 26 the two triangles are equal in every respect.

$O\ M$ and $O\ M^1$ are numerically equal.
$M\ P$ and M^1P^1 are numerically equal.
$O\ P$ and $O\ P^1$ are numerically equal.

In the figure $O\ P$ and $O\ P^1$ have the same sign.
$O\ M$ and $O\ M^1$ are of opposite sign as also are $M\ P$ and $M^1\ P^1$

$$M\ P = -\ M^1P^1 \ \therefore\ -\ M\ P = M^1P^1$$
$$O\ M = -\ O\ M^1 \ \therefore\ -\ O\ M = O\ M^1$$

The functions of the angle $(180°+A)$

To prove that $\sin(180°+A) = -\sin A$

$$\text{Sin } BOP^1 = \frac{P^1M^1}{OP^1} = \frac{-PM}{OP} \therefore \sin(180°+A) = -\sin A$$

To prove that $\cos(180°+A) = -\cos A$

$$\text{Cos } BOP^1 = \frac{OM^1}{OP^1} = \frac{-OM}{OP} \therefore \cos(180°+A) = -\cos A$$

To prove that $\tan(180°+A) = \tan A$

$$\text{Tan } BOP^1 = \frac{P^1M^1}{OM^1} = \frac{-PM}{-OM} = \frac{PM}{OM} \therefore \tan(180°+A) = \tan A$$

To prove that $\operatorname{cosec}(180°+A) = -\operatorname{cosec} A$

$$\text{Cosec } BOP^1 = \frac{OP^1}{P^1M^1} = \frac{-OP}{PM} \therefore \operatorname{cosec}(180°+A) = -\operatorname{cosec} A$$

To prove that $\sec(180°+A) = -\sec A$

$$\text{Sec } BOP^1 = \frac{OP^1}{OM^1} = \frac{-OP}{OM} \therefore \sec(180°+A) = -\sec A$$

To prove that $\cot(180°+A) = \cot A$

$$\text{Cot } BOP^1 = \frac{OM^1}{P^1M^1} = \frac{-OM}{-PM} = \frac{OM}{PM} \therefore \cot(180°+A) = \cot A$$

A great variety of examples can be set from the angles $(90°-A)$ $(90°+A)$ $(180°-A)$ and $(180°+A)$, but if the signs in the different quadrants are understood and care is taken when transposing them in the equations, after a little practice no difficulty should be experienced.

NOTES

Examples for Exercise.

(1) $\dfrac{\sin A}{\cos A} + \dfrac{\sec A}{\operatorname{cosec} A} = 2 \tan A.$

(2) $\dfrac{\cot A}{\operatorname{cosec} A} - \dfrac{\sin A}{\tan A} = 0.$

(3) $\dfrac{\cot A}{\operatorname{cosec} A} = \dfrac{1}{\sec A}.$

(4) $\dfrac{\sin A}{\cos A, \tan^2 A} = \dfrac{1}{\tan A}.$

(5) $\cos A = \dfrac{\cot A, \tan A}{\sec A}.$

(6) $\dfrac{1}{(\sec A + 1)(\sec A - 1)} = \dfrac{1}{\sin^2 A} - 1.$

(7) $\dfrac{1}{(\operatorname{cosec} A - 1)(\operatorname{cosec} A + 1)} = \left(\dfrac{1}{\cos A} + 1\right)\left(\dfrac{1}{\cos A} - 1\right).$

(8) $\dfrac{1}{\sqrt{1 + \cot^2 A}} = \sqrt{1 - \dfrac{1}{\sec^2 A}}$

(9) $\dfrac{1}{\sqrt{1 + \cot^2 A}} = \dfrac{1}{\sqrt{1 + \dfrac{1}{\sec^2 A - 1}}}$

(10) $\dfrac{1}{1 + \tan^2 A} = \left(1 - \dfrac{1}{\operatorname{cosec} A}\right)\left(1 + \dfrac{1}{\operatorname{cosec} A}\right)$

(11) $(\operatorname{cosec} A - \sin A)(\operatorname{cosec} A + \sin A) = \cot^2 A + \cos^2 A.$

(12) $(\sin A + \sec A)(\sec A - \sin A) = \tan^2 A + \cos^2 A.$

(13) $(\cos A + \operatorname{cosec} A)(\cos A - \operatorname{cosec} A) = -\sin^2 A - \cot^2 A.$

(14) $(2 - \operatorname{cosec} A)(2 + \operatorname{cosec} A) = (\sqrt{3} + \cot A)(\sqrt{3} - \cot A).$

(15) $\sqrt{1 + \cot^2 A} = \dfrac{1}{\sqrt{1 - \cos^2 A}}$

(16) $(\cos A + \sin A)^2 + (\cos A - \sin A)^2 = 2.$

(17) $(1 - \cot A)^2 = \operatorname{cosec}^2 A - 2 \cot A.$

(18) $(\tan A + 2)^2 = 3 + \sec^2 A + 4 \tan A.$

(19) $\dfrac{\cot^2 A}{1 + \operatorname{cosec} A} = \operatorname{cosec} A - 1.$

(20) $\operatorname{cosec}^2 A - \cot A, \cos A, \operatorname{cosec} A - 1 = 0.$

(21) $\dfrac{1}{\tan^2 A} - \dfrac{1}{\sin^2 A} = -1.$

(22) $\operatorname{cosec} A = 4\sqrt{3}$, find the other ratios.

(23) Prove that $\cot^2 60° = \tan^2 30°.$

(24) If $2 \sin A = \cdot 5$, find the other ratios.

(25) If $1 - \sin^2 A = 1 - \cos^2 A$, find the value of A.
($Ans.$ $A = 45°.$)

(26) Show that $\sin (90 - A) = \cos A.$

(27) Show that $\sin (90 + A) = \cos A.$

(28) Show that $\sin (90 - A) = \sin (90 + A).$

PROBLEMS IN RIGHT-ANGLED PLANE TRIGONOMETRY.

Heights are said to be inaccessible when it is not possible to measure their perpendicular height by being able to get to their bases.

Distances are said to be inaccessible when they cannot be measured directly.

The angle of elevation is the vertical angle above the horizontal plane at the level of the eye.

The angle of depression is the vertical angle below the horizontal plane at the level of the eye.

A horizontal angle is an angle in a horizontal plane.

Many of the following examples are the exact questions that have been set at the examinations, and in all cases they are very similar. In drawing the diagrams for the problems, it is advisable to first draw them in pencil, in order to get the proper dimensions, and afterwards to ink them in.

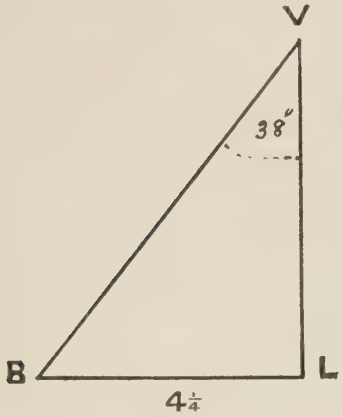


Fig. 4.

EXAMPLE 1.—**The horizontal angle by sextant between a lighthouse abeam and a beacon at right angles to it was 38°. The distance between the lighthouse and beacon was $4\frac{1}{4}$ miles. How far was the vessel from the lighthouse?**

CONSTRUCTION.—Draw a line as $B\,L$ in Fig. 4 making it $4\frac{1}{4}$ parts in length to any convenient scale, then L is the position of the lighthouse and B the position of the beacon, make $L\,V$ perpendicular to $B\,L$. As we know the angle at V is 38°, the angle at B must be $90° - 38° = 52°$, $\therefore$ make angle $B = 52°$, and where this line meets the perpendicular from L at V will be the position of the vessel. It is required to find $L\,V$, the distance of the vessel from the lighthouse.

Explanation of figure (to be written at the examination).

In figure $B\,V\,L$, let L represent the lighthouse,
B ,, the beacon,
and V ,, the position of vessel.

In right-angled triangle $B\,L\,V$, angle $L = 90°$, angle $B = 52°$, angle $V = 38°$, side $B\,L = 4\frac{1}{4}$; to find $L\,V$;

$$\frac{L\,V}{B\,L} = \text{cotan } V, \quad \therefore L\,V = B\,L \times \cot V.$$

$B\,L = 4{\cdot}25$	log	0·628389
$V = 38°$	cot	10·107190
$V\,L = 5{\cdot}44$	log	0·735579

$\therefore$ Dist. of vessel from lighthouse = 5·44 miles.

EXAMPLE 2.—**A ship on a south-westerly course sights a beacon bearing South, and after running 7 miles it was abeam, and after a further 3 miles it bore East. Find the course the ship was steering.**

As the object was first bearing South, and after running 10 miles was bearing East—that is, a right angle—the angle at the beacon is an angle in a semicircle of which 10 miles is the diameter. Therefore, as in Fig. 5, draw $A\ B$ in a south-westerly direction equal to 10 miles, bisect it at E, and with E as centre and $E\ B$ as radius describe the semi-circle $B\ C\ A$; make $A\ D = 7$, and draw $D\ C$ perpendicular to $A\ B$, and where this meets the semicircle at C will be the position of the beacon.

Join $E\ C$, $A\ C$, and $B\ C$.

Then $A\ C$ is the first line of bearing, $D\ C$ when abeam, and $B\ C$ when bearing East, it is required to find the angle $B\ A\ C$ = ship's course.

In triangle $D\ E\ C$, $D = 90°$, $E\ C = A\ E = 5$; $D\ E = 2$. To find angle E.

$$\frac{D\ E}{E\ C} = \text{cosine } E, \quad \therefore \cos E = D\ E \div E\ C.$$

$D\ E = 2$ log $= 10{\cdot}301030$ (+ 10 to index)

$E\ C = 5$ log $= 0{\cdot}698970$

$E = 66° 25' 19''$ cos $= 9{\cdot}602060$

$\therefore$ angle $B\ E\ C = 66° 25' 19''$.

Angle $B\ E\ C$ is an angle at the centre of the circle $A\ C\ B$, and $B\ A\ C$ is an angle at the circumference on the same arc $B\ C$.

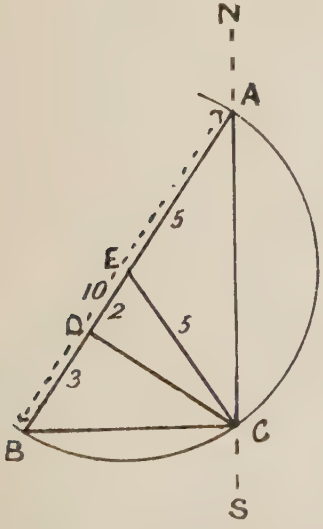


Fig. 5.

* $\therefore\ B\ A\ C = \frac{1}{2}\ B\ E\ C.$

$= 66° 25' 19'' \div 2$

$= 33° 12' 39''.$

$\therefore$ Ship's course = S. 33° 12′ 39″ W.

Short method of finding angle E. In triangle $D\ E\ C$,

$$\frac{D\ E}{E\ C} = \text{cosine } E.$$

$$\therefore \quad \frac{2}{5} = \text{cosine } E.$$

i.e., $\cdot 400 =$ natural cosine E.

$\therefore$ angle $E = 66° 25' 20''$.

*Angle $B\ E\ C = 180° - A\ E\ C$.

Also $A + C = 180° - A\ E\ C$.

$\therefore\ B\ E\ C = A + C$.

But angles A and C are equal, as their opposite sides are equal.

$\therefore\ C = \frac{1}{2}\ B\ E\ C$,

and $A = \frac{1}{2}\ B\ E\ C$.

EXAMPLE 3.—**A and B are two vessels steaming in line ahead at 10 knots. B being 1 mile astern of A is ordered to take her position on A's starboard beam distant 1 mile and to alter course 30° in carrying out the order. What speed must B steam at?**

CONSTRUCTION.—Draw a line $B\,C$ (Fig. 6) to represent the course A and B are steering at commencement, and let B be the position of vessel B at that time. As we have a definite alteration of course given = 30°, make angle $C\,B\,D = 30°$. From the position B_1 anywhere on $B\,D$ draw B_1A_1 perpendicular to $B\,C$, let $B_1A_1 = 1$ mile. Make $B\,A = B_1A_1$, then B has to steam from B to B_1 whilst A steams from A to A_1 at 10 knots.

In triangle $B\,A_1B_1$, $A_1 = 90°$, $A_1B_1 = 1$, angle $B = 30°$. To find A_1B and $B\,B_1$.

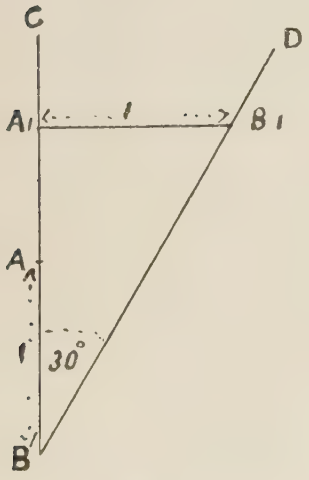


Fig. 6.

$$\frac{A_1B}{A_1B_1} = \cot B \qquad \frac{B\,B_1}{A_1B_1} = \operatorname{cosec} B$$

$$\therefore \frac{A_1B}{1} = \cot B \qquad \frac{B\,B_1}{1} = \operatorname{cosec} B$$

$$A_1B = \cot B \qquad B\,B_1 = \operatorname{cosec} B$$

A_1B = nat. cot 30° = 1·732 — $B\,B_1$ = nat. cosec. 30° = 2·0

$A_1B = 1{\cdot}732.$ $\qquad B\,B_1 = 2.$

$B\,A_1 = 1{\cdot}732$
$A\,B = 1{\cdot}000$
$A\,A_1 = \cdot732$

Therefore B has to steam 2 miles whilst A steams ·732 at 10 knots; to find the speed of B by proportion.

As $\cdot732 : 2 :: 10 : x$ (where x = B's speed).

$$\frac{2 \times 10}{\cdot732} = \frac{20}{\cdot732}$$

·732)20·00(27·32
1464
·5360
5124
·2360
2196
1640

B's speed = 27·32 knots.

We have worked this case without the use of logs for the benefit of the candidates' instruction, and, as will be seen, it greatly shortens and simplifies the work, it can be seen at once that $\frac{A_1B}{1}$; *i.e.*, A_1B divided by $1 = A_1B$.

$\therefore$ A_1B = natural cotangent B or 30°, and no calculation beyond this is necessary as we have the natural cotangent of 30° = $\sqrt{3} = 1{\cdot}732$.

EXAMPLE 4.—**A steamer on a N.W. course observes a pair of beacons of a measured mile in line on the starboard bow and after steaming 1·4 miles the other pair of beacons were in line, find the course to steer when running on the measured mile.**

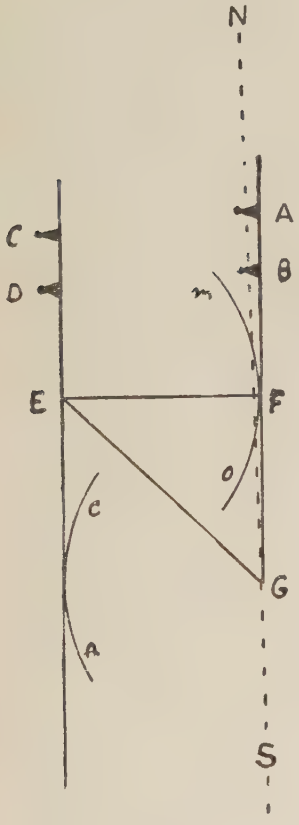


Fig. 7.

The difficulty in this problem for beginners is to construct the diagram for it; it is in reality a problem where a straight line crosses two parallel lines, the two parallel lines are those in line with each pair of beacons, they are, therefore, 1 mile apart.

In Fig. 7 these lines are *A B G* and *C D E*, the crossing line is the ship's track *G E*.

Put in the *N* and *S* line, let *G* be the position the vessel started from, make *G E* = 1·4 to any scale and N. 45° W. Now we know the vessel was on one parallel at *G* and another at *E*, and that the parallels were 1 mile apart, therefore draw the parallels passing through *E* and *G*, and make *E F* perpendicular to *G F* the first parallel, then *E F* is the course on the measured mile, and to find its direction we must first find angle *G E F*.

To draw the two parallels, place the point of the dividers on *G* and with radius of 1·0 mile describe arc "*e c*," then with the point of the dividers on *E* and the same radius describe an arc "*o m*," then a line through *E* just touching arc "*e c*" and a line through *G* just touching arc "*o m*" will be the two parallel lines required.

In triangle *E F G*, angle *F* = 90° (constr.), side *E F* = 1·0, side *E G* = 1·4, to find angle *E*.

$$\frac{E\,G}{E\,F} = \text{secant } E.$$

E G =	1·4	log	10·146128 (+ 10 to index)
E F =	1·0	log	0·000000
E = 44° 25′		sec	10·146128

To find the course on the measured mile.

Direction of *E G* =	S.	45° E. (left)
Angle *E* =		44 25′ (left)
Direction of *E F* =	S.	89° 25′ E.
∴ Course =	S.	89° 25′ E.
or	N.	89° 25′ W.

EXAMPLE 5.—**A vessel at sea sights a beacon bearing N.W. whose elevated angle was 1° 48′, and at the same time another beacon bearing N.E. whose elevated angle was 1° 30′, both beacons being of the same height. Find the course the vessel must steer to pass midway between the beacons.**

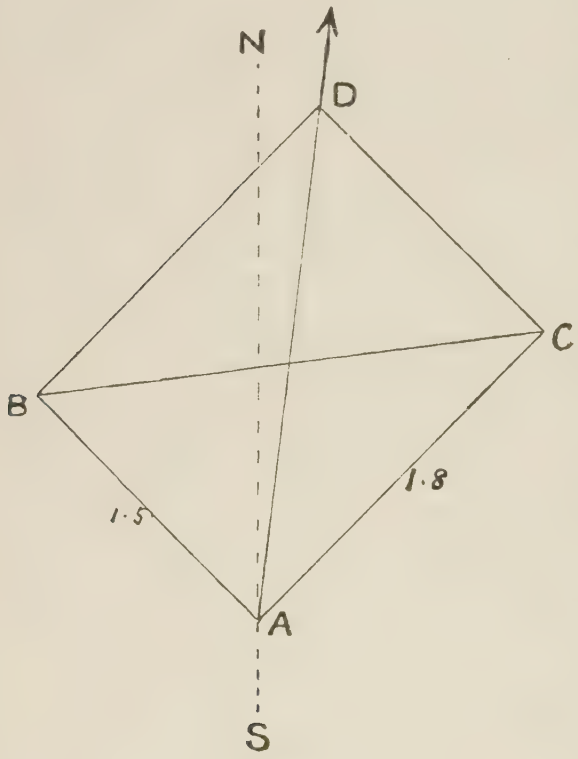


Fig. 8.

In this case we have a right-angled triangle with the elevated angle of each beacon to give us the perpendicular sides. Now, the distances from these two beacons are in the same ratio as their angular heights, but inversely, for, as we approach the beacon its altitude increases, and as we go away from the beacon its altitude decreases.

We can, therefore, assume that the altitude of one beacon is the distance off the other and *vice versa* ; then, with these two sides or rather proportions, we can find the angles.

CONSTRUCTION.—Let A be the position of the vessel ; make $A\ B$ equal to 1° 30′ = 1·5 to any convenient scale, and $A\ C$ = 1° 48′ = 1·8 in the same scale. Join $B\ C$. From C draw a line parallel to $A\ B$, and from B draw a line parallel to $A\ C$ meeting the first parallel at D. Join $A\ D$. Then angle $N\ A\ D$ is the course to steer to pass midway between beacons B and C, for $A\ D$ and $B\ C$ are diagonals of the rectangle $A\ B\ D\ C$.

In R.A. triangle $A\ C\ D$, given $A\ C$ = 1·8, $C\ D = A\ B$ = 1·5, to find angle $D\ A\ C$.

$\frac{D\ C}{A\ C}$ = tan A, $\therefore$ tan $A = D\ C \div A\ C$.

$D\ C$ = 1·5	log 0·176091 (+ 10)
$A\ C$ = 1·8	log 0·255273
$D\ A\ C$ = 39° 48′ 20″	log tan 9·920818
$N\ A\ C$ = 45° 0′ 0″	
$N\ A\ D$ = 5° 11′ 40″	Course = N. 5° 11′ 40″ E.

EXAMPLE 5 (*continued*).

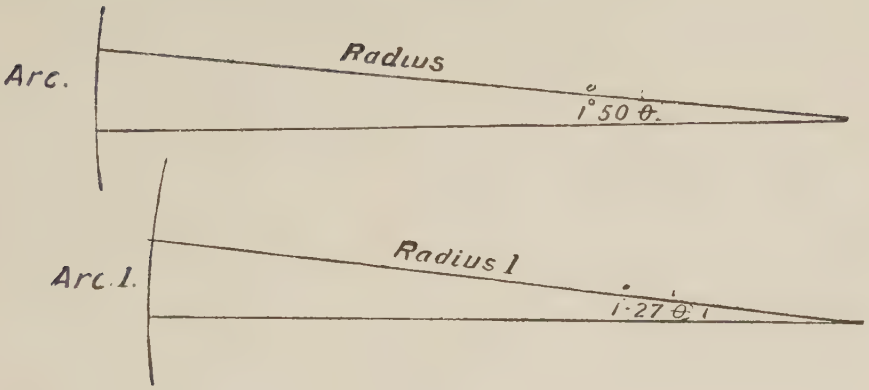


Fig. 9.

To prove that the distances from the beacons are inversely as their altitudes, we resort to circular measure, and assume that the vertical heights of the beacons are arcs of vertical circles passing through their tops and bases. In Fig. 9, "arc" and "arc 1" represent the beacons.

By circular measure we have :—

$$\frac{\text{arc}}{\text{radius}} = \text{angle in circular measure} = \theta\,.$$

also $$\frac{\text{arc 1}}{\text{radius 1}} = \text{angle in circular measure} = \theta\,1.$$

i.e., $$\text{arc} = \text{radius} \times \theta.$$

and $$\text{arc 1} = \text{radius 1} \times \theta\,1.$$

As the beacons are of the same height, arc = arc 1,

$\therefore$ $$\text{radius} \times \theta = \text{radius 1} \times \theta\,1,$$

from which by transposing we get

$$\frac{\text{radius}}{\text{radius 1}} = \frac{\theta\,1}{\theta}\,.$$

That is, the first **radius** or **distance** is to the second **radius** as the **second angle** is to the **first angle.** They are in the same ratio inversely.

EXAMPLE 6.—**A vessel on a N. 45° E. course observes two headlands in transit bearing N. by E., and after steaming 10 miles the horizontal angle between the points was at its maximum angle of 90°. Find the distance between the points.**

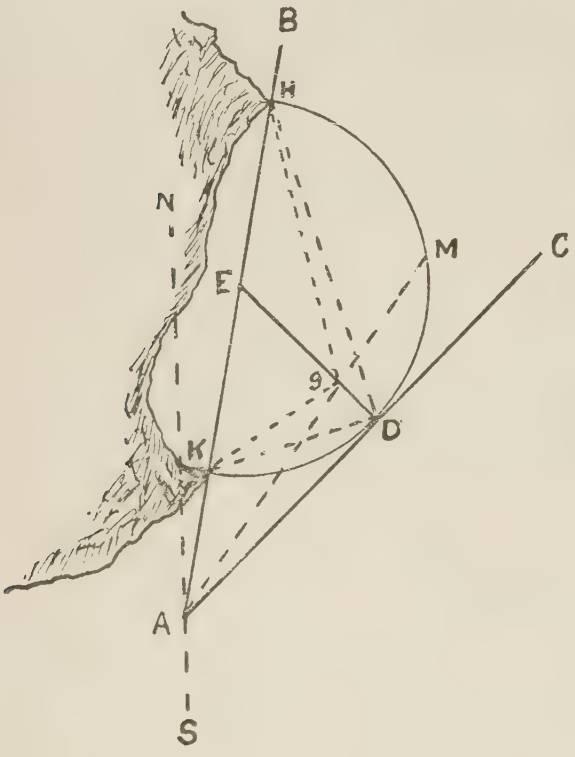


Fig. 10.

CONSTRUCTION.—Draw in the N. and S. line, and from it lay off $A\ B$ at N. 11° 15′ E., the bearing of the headlands in line, and $A\ C$ at N. 45° E., the ship's course. Then angle $B\ A\ C = 33°\ 45'$. On $A\ C$ make $A\ D = 10$, the distance steamed, draw $E\ D$ perpendicular to $A\ C$. With centre E and radius $E\ D$ describe the semicircle $K\ D\ H$, then K and H will be the positions of the two headlands on $A\ B$.

For angle 90° is an angle in a semicircle, and as the angle did not become greater the course must have been a tangent to the circle with $H\ K$ as diameter, and as a tangent is always at right angles to the radius, we make $D\ E$ at right angles to $A\ C$.

If the vessel had steered on $A\ M$, when she arrived at "g," the angle would have been $H\ g\ K$, which is obviously more than a right angle. Similarly, if the vessel's course had been outside the circle altogether, the horizontal angle would have been less than 90° at all times.

$E\ D$, $E\ K$, and $E\ H$ are all radii of the circle $H\ D\ K$.

$\therefore$ $H\ E = E\ D$ and $E\ K = E\ D$, and $H\ K$ = twice $E\ D$.

In R.A. triangle $E\ D\ A$, angle $D = 90°$, $A\ D = 10$, angle $A = 33°\ 45'$, to find $E\ D$.

$$\frac{E\ D}{A\ D} = \tan A, \therefore E\ D = A\ D \times \tan A.$$

$A\ D = 10$	log	1·000000
$A = 33°\ 45'$	log tan	9·824893
$E\ D = 6{\cdot}68$	log	0·824893
2		
13·36		

$\therefore$ Distance between headlands = 13·36 miles.

EXAMPLE 7.—**Two ships are both steaming North at 10 knots, one 5 miles from the other and bearing due East. The one to the Westward has orders to close the other to 1 mile and at the same time to increase her speed to 12 knots. Find the course she will have to steer to do that maintaining her bearing from the other vessel. Also find the time she will take before being in that formation.**

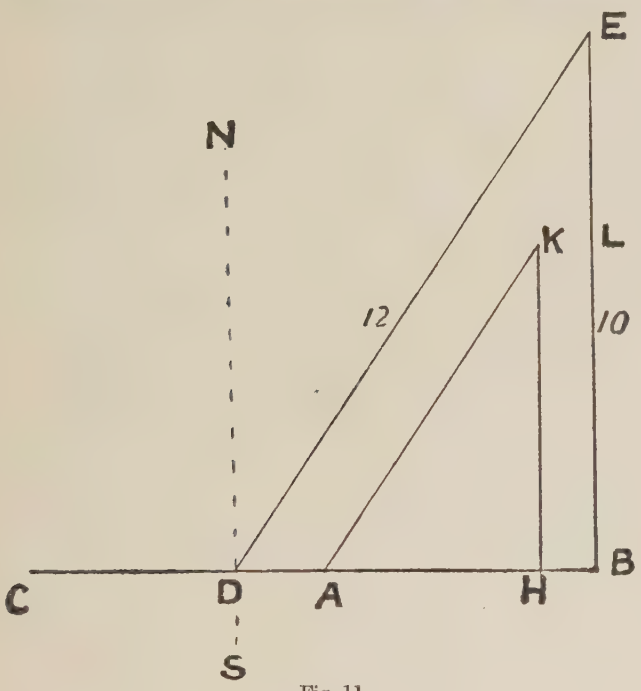


Fig. 11.

Draw the base line $B\,A\,C$ in the E. and W. direction.

Let B represent the vessel to the eastward, make $B\,H = 1$ to any convenient scale, and $B\,A = 5$, then A is the first position of the vessel to the westward. Vessel at A has to alter course to starboard and approach the vessel B, keeping on the beam bearing whilst doing so, her final distance from B being 1 mile. The amount that A must alter course depends on the speed of the two vessels, for if A alters course too much she will pass under B's stern, and if too little, she will pass ahead of B.

To find A's alteration of course, make $B\,E = 10$ miles due North from B, then, with E as centre and radius 12 describe an arc cutting $B\,C$ at D, join $E\,D$, and angle $N\,D\,E$ is the course that A must steer. But $N\,D\,E = D\,E\,B$ by parallels, therefore $D\,E\,B = A$'s course.

As A is the true position of vessel A, make $A\,K$ parallel to $D\,E$, the course line, and $H\,K$ parallel to $B\,E$, B's course line, then K will be the final position of vessel A and L the final position of vessel B. In R.A. triangle $A\,K\,H$, angle $A\,K\,H$ = angle $D\,E\,B$ (as they are similar triangles), side $A\,H = 4$, side $A\,K$ is the distance A has to steam to close in the 4 miles.

TO FIND THE COURSE.

In R.A. triangle $D\,E\,B$.
Given $D\,E$ and $B\,E$.
To find angle E.

$\frac{D\,E}{B\,E} = \sec E$.

$D\,E = 12$ log 1·079181
$B\,E = 10$ log 1·000000
log sec $\overline{10}$·079181

Course, N. 33° 33′ 26″ E.

TO FIND DISTANCE TO STEAM.

In R.A. triangle $A\,K\,H$.
Given angle K.
side $H\,A$.
To find $A\,K$ = distance.

$\frac{A\,K}{A\,H} = \text{cosec } K$, $\therefore \text{cosec } K \times A\,H = A\,K$.

$K = 33°\ 33'\ 26''$ cosec 10·257456
$H\,A = 4$ log 0·602060
$A\,K = 7{\cdot}236$ log $\overline{0}$·859516

Distance = 7·236 miles.

TO FIND THE TIME TAKEN.

As 12 : 7·236 : : 60m. to x (required time)

$$\frac{7{\cdot}236 \times 60}{12} = 7{\cdot}236 \times 5$$

$$= 36{\cdot}180 \text{ minutes.}$$

EXAMPLE 8.—**Three buoys were each two miles apart, and a vessel was moored so that she was equidistant from each buoy. What was that distance ?**

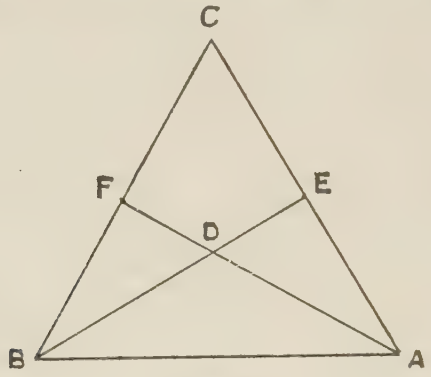


Fig. 12.

In Fig. 12. $A\ B\ C$ is an equilateral triangle, each side being equal to 2, then each angle $= 60°$. Bisect A by $A\ D\ F$ and bisect B by $B\ D\ E$, then D is the centre of triangle $A\ B\ C$, and it is required to find $D\ A$, or $D\ B$.

In triangle $A\ D\ E$, angle $E = 90°$, $A\ E = \frac{1}{2}\ A\ C = 1$.

Angle $A = \frac{1}{2}\ C\ A\ B = 30°$; to find $A\ D$

$$\frac{A\ D}{A\ E} = \sec A, \therefore A\ D = A\ E \times \sec A.$$

$A\ E = 1$	$\log =$	0·000000
$A = 30°$	sec $=$	10·062469
$A\ D = 1{\cdot}154$	$\log =$	10·062469 (reject 10).

$\therefore$ Distance of vessel from buoys = 1·154 miles.

This problem can more easily be worked with the known numerical ratios of 30° —that is, $\sec 30° = \frac{2}{\sqrt{3}}$.

Hence $$\frac{A\ D}{A\ E} = \frac{2}{\sqrt{3}} \therefore A\ D = \frac{1 \times 2}{\sqrt{3}} = \frac{2}{\sqrt{3}}$$

Multiplying both numerator and denominator by $\sqrt{3}$,

$$A\ D = \frac{2 \times \sqrt{3}}{3} = \frac{2 \times 1{\cdot}732}{3} = \frac{3{\cdot}464}{3}.$$

$A\ D = 1{\cdot}1547$. *Ans.*

OBLIQUE-ANGLED PLANE TRIGONOMETRY.

In an oblique-angled triangle the angles and sides are strictly proportional to each other, the longest side is opposite the largest angle and the shortest side is opposite the smallest angle, etc.

The sides may be of any length, and the angles of any magnitude, less than 180° ; providing the three straight lines, comprising the sides, enclose a space.

Of the six parts in any triangle, three must be given in order to find the remainder ; and of these parts, one must be a side.

As every triangle contains 180°, if any two angles be known the third can be found by subtracting the sum of the known angles from 180°. Similarly, if one angle is known the sum of the other two angles can be found by subtracting the known angle from 180°, thus :—

$$A + B + C = 180°, \therefore B + C = 180° - A.$$

There are three methods of solving oblique-angled triangles, the method used depending on the parts which are given.

Case 1.—When one side and two angles are given.

Case 2.—When two sides and the angle opposite one of them are given.

(Cases 1 and 2 are worked by the same formula.)

Case 3.—When two sides and the angle between them are given.

Case 4.—When all three sides, but no angles are given.

CASES 1 AND 2.—**When two sides and an angle opposite to one of them are given or two angles and a side opposite one of them are given.**

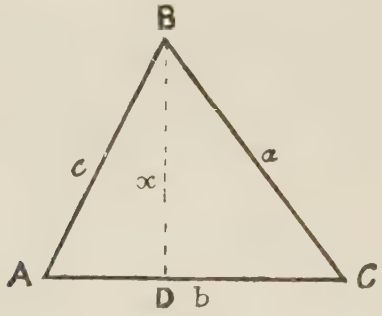


Fig. 13.

This is solved by what is known as the "**rule of sines**," and its basis is that the sides are in the same proportion to each other as the sines of their opposite angles.

From this it becomes simply a matter of proportion :—

In triangle $A\ B\ C$, "a" is to "b" in the same proportion that sin A is to sin B; expressing this in the form of an equation, we have :— $\frac{a}{b} = \frac{\sin A}{\sin B}$, or by transposing we have $\frac{a}{\sin A} = \frac{b}{\sin B}$.

$$\text{Similarly, } \frac{b}{\sin B} = \frac{c}{\sin C} = \frac{a}{\sin A}.$$

$$\text{Also, } \quad \frac{\sin B}{b} = \frac{\sin C}{c} = \frac{\sin A}{a}.$$

PROOF.—This is derived from R.A. trigonometry. Make $B\ D$ perpendicular to $A\ C$, let $B\ D = x$.

$$\text{Then} \qquad \frac{x}{c} = \sin A\ ; \qquad \frac{x}{a} = \sin C.$$

$$\therefore \qquad x = c \sin A\ ; \ \therefore x = a, \sin C.$$

Things which are equal to the same are equal to one another.

$$\therefore \quad c, \sin. A = a \sin C.$$

$$\text{Also} \qquad \frac{c}{a} = \frac{\sin C}{\sin A} \text{ and } \frac{c}{\sin C} = \frac{a}{\sin A}, \text{ etc.}$$

Worked Example I.

In triangle $A\ B\ C$ (Fig. 14), given angle $C = 62°$, side $c = 244{\cdot}3$, side $b = 205{\cdot}62$, to find angles A and B and side a.

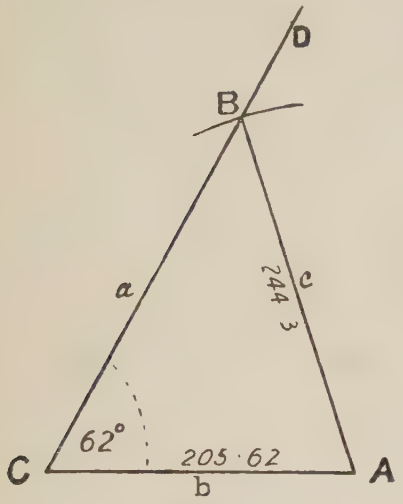


Fig. 14.

To construct the triangle draw the middle part first, thus C and c being opposites, draw b to any scale = 205·6, make angle $A\ C\ D = 62°$, then with 244·3 in the compasses and centre A describe an arc cutting $C\ D$ at B; join $A\ B$, and this will complete the triangle.

As we have c and b given and angle C opposite to c, we can only find B the angle opposite the given side b from these given parts. In all cases, whether it be side or angle, write down the required part first, place the opposite side or angle under it, and complete the equation, thus :—

$$\begin{matrix}\text{(Req.)} & \dfrac{\sin B}{b} \\ \text{(Given)} & \dfrac{\sin C}{c}\end{matrix} = .$$

Multiplying both sides by b, we get :—

$$\sin B = \frac{b \times \sin C}{c}.$$

i.e., $\log \sin B = \log b + \log \sin C - \log c$.

b	$= 205{\cdot}62$	$\log = 2{\cdot}313065$
C	$= 62°\ 00'$	$\sin = 9{\cdot}945935$
		$12{\cdot}259000$
c	$= 244{\cdot}3$	$\log = 2{\cdot}387923$
Angle B	$= 48°\ 00'$	$\sin = 9{\cdot}871077$

To find side "a" :—

$$\frac{a}{\sin A} = \frac{b}{\sin B},\ \therefore\ a = \frac{\sin A \times b}{\sin B}.$$

i.e., $\log a = \log \sin A + \log b + \log \operatorname{cosec} B$.

Angle C	$= 62°\ 0'$		
B	$= 48°\ 0'$		
	$A = 70°\ 0'$	$\sin =$	$9{\cdot}972986$
	$b = 205{\cdot}62$	$\log =$	$2{\cdot}313065$
	$B = 48°\ 0'$	$\operatorname{cosec} =$	$10{\cdot}128927$
		$\log =$	$22{\cdot}414978$ (reject 20)
Angle A	$= 70°\ 0'$	Side a	$= 260$

In this last case it will be noticed we have used the reciprocal of sin B—that is, cosec B—and thus made all the logs additive to ,multiply by the reciprocal of a ratio produces the same result as dividing by the ratio itself.

Worked Example II.

In triangle $A\ B\ C$, given $A = 70°$, $B = 48°$, $a = 260$. Find the remaining parts.

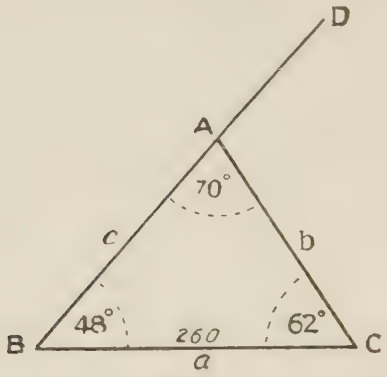


Fig. 15.

Construction.—Make $B\ C = 260$ to any scale, and angle $C\ B\ D = 48°$. Add the value of A and B together, and take their sum from 180°. This gives us 62° for angle C. Lay off a line from C forming an angle of 62° with $B\ C$. This line will strike $B\ D$ in A, and will complete the triangle $A\ B\ C$.

To find b:—

$$\frac{b}{\sin B} = \frac{a}{\sin A}, \quad \therefore\ b = \frac{\sin B \times a}{\sin A}.$$

$$\therefore\ \log b = \log \sin B + \log a + \log \operatorname{cosec} A.$$

$B = 48°$	sin	=	9·871073
$a = 260$	log	=	2·414973
$A = 70°$	cosec	=	10·027014
$b = 205{\cdot}62$	log	=	22·313060 (reject 20)

To find c:—

$$\frac{c}{\sin C} = \frac{a}{\sin A}, \quad \therefore\ c = \frac{\sin C \times a}{\sin A}.$$

$C = 62°$	sin	=	9·945935
$a = 260$	log	=	2·414973
$A = 70°$	cosec	=	10·027014
$c = 244{\cdot}3$	log	=	22·387922 (reject 20)

$\therefore\ C = 62°\ ;\ b = 205{\cdot}62\ ;\ c = 244{\cdot}3.$

THE AMBIGUOUS CASE. Worked Example 3.

When two sides of a triangle are given and the angle opposite the smaller side, the triangle is said to be ambiguous, inasmuch as it has two solutions—that is to say, two separate triangles can be constructed from the given parts.

Example.—**In triangle $A\,C\,B$ (Fig. 16), given $B = 38°\ 0'$, side $b = 140$, side $c = 206$, to find the other parts.**

To construct the triangle, draw the line $A\,B$ or c=206, and from B make the angle $A\,B\,D$=38°; with 140 in the compasses and A as centre describe the arc $C\,C_1$ cutting $B\,D$ at C and C_1, join $A\,C$ and $A\,C_1$. Then $A\,C\,B$ and $A\,C_1B$ are the two triangles we obtain by using the given parts.

In triangle $A\,B\,C$, to find angle C :—

$$\frac{\sin C}{c} = \frac{\sin B}{b},\ \therefore \sin C = \frac{c \times \sin B}{b}.$$

i.e., $\log \sin C = \log c + \log \sin B - \log b$.

$B = 38°\ 0'$	sin = 9·789342	$C = 64°\ 56'\ 42''$
$c = 206$	log = 2·313867	$B = 38\ \ 0\ \ 0$
	12·103209	$102°\ 56'\ 42''$
$b = 140$	log = 2·146128	$180\ \ 0\ \ 0$
$C = 64°\ 56'\ 42''$	sin = 9·957081	$A = 77°\ \ 3'\ 18''$

To find a :—

$$\frac{a}{\sin A} = \frac{b}{\sin B},\ \therefore a = \frac{\sin A \times b}{\sin B}.$$

i.e., $\log a = \log \sin A + \log b + \log \operatorname{cosec} B$.

$A = 77°\ \ 3'\ 18''$	sin 9·988820
$b = 140$	log 2·146128
$B = 38°\ \ 0'\ \ 0''$	cosec 10·210658
$a = 221{\cdot}6$	log 22·345606 (reject 20)

$\therefore$ in triangle $A\,C\,B$, angle $A = 77°\ 3'\ 18''$, angle $C = 64°\ 56'\ 42''$, angle $B = 38°$, side $a = 221{\cdot}6$, side $c = 206$, side $b = 140$.

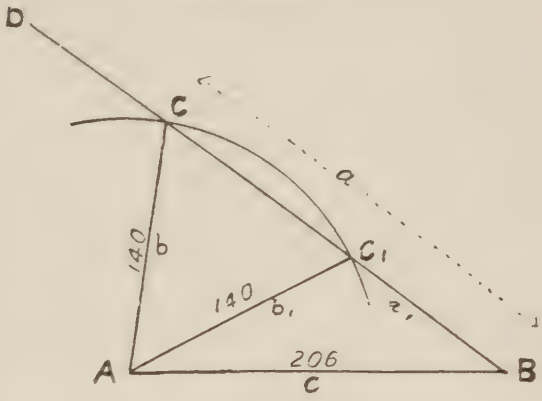


Fig. 16.

Now, in triangle $A\,C\,C_1$, because $A\,C = A\,C_1$ angle C = angle C_1 and angle C_1 is supplement of $A\,C_1B$, $\therefore$ angle C also is supplement of angle $A\,C_1B$, so that $180° - C$ = angle $A\,C_1B$.

	$180°\ \ 0'\ \ 0''$
$C =$	$64\ \ 56\ \ 42$
$A\,C_1B =$	$115\ \ \ 3\ \ 18$

In triangle $A\,C_1B$, given $B =$ $38°\ \ 0'\ \ 0''$

and $C_1 =$ $115\ \ \ 3\ \ 18$

$153°\ \ 3'\ 18''$

$180\ \ \ 0\ \ \ 0$

Angle $A =$ $26°\ 56'\ 42''$

To find a_1 :—

$$\frac{a_1}{\sin A} = \frac{b_1}{\sin B},\ \therefore a_1 = \frac{\sin A \times b_1}{\sin B}.$$

i.e., $\log a_1 = \log \sin A + \log b_1 + \log \operatorname{cosec} B$.

$A = 26°\ 56'\ 42''$	sin = 9·656228
$b_1 = 140$	log = 2·146128
$B = 38°\ 0'\ 0''$	cosec = 10·210658
$a_1 = 103{\cdot}05$	
	log = 22·013014

$\therefore$ in triangle $A\,C_1B$, angle $B = 38°\ 0'\ 0''$, $C_1 = 115°\ 3'\ 18''$, $A = 26°\ 56'\ 42''$, side $a_1 = 103{\cdot}05$, $b_1 = 140$, $c = 206$.

Worked Example 4.

Case 3.—**Given two sides and the angle contained between them.**

The difference in the sides—*i.e.*, $(a - b)$ is to the tangent of half the difference of the opposite angles; *i.e.*, tan $\frac{1}{2}(A - B)$ as the sum of the sides $(a + b)$ is to the tangent of half the sum of the opposite angles tan $\frac{1}{2}(A + B)$; from this we get what is known as the tangent formula :—

$$\frac{\tan \frac{1}{2}(A - B)}{\tan \frac{1}{2}(A + B)} = \frac{a - b}{a + b}.$$

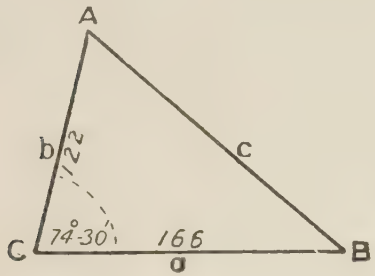


Fig. 17.

Worked Example 1.—**In triangle $A\,B\,C$ (Fig. 17), given $a = 166$, $b = 122$, the included angle $C = 74° 30'$, to find the other parts.**

In the above formula $a - b$ and $a + b$ are easily found by taking the difference and the sum of the two given sides; $\frac{1}{2}(A + B)$ is found by subtracting the given angle C from 180°, and thus obtaining $(A + B)$ this divided by 2 is obviously $\frac{1}{2}(A + B)$.

i.e., $A + B + C = 180$, $\therefore A + B = 180 - C$.

The part that has to be calculated is, therefore, $\frac{1}{2}(A - B)$, and by transposing we obtain

$$\tan \tfrac{1}{2}(A - B) = \frac{\tan \frac{1}{2}(A + B) \times a - b}{a + b}.$$

i.e., $\log \tan \frac{1}{2}(A - B) = \log \tan \frac{1}{2}(A + B) + \log (a - b) - \log (a + b)$.

$a = 166$	$\frac{1}{2}(A + B) = 52° 45'$	tan 10·118948
$b = 122$	$a - b = 44$	log 1·643453
$a + b = 288$		11·762401
$a - b = 44$	$a + b = 288$	log 2·459392
$C = 74\ 30$	$\frac{1}{2}(A - B) = 11° 21' 37''$	tan 9·303009
$180\ 0$	$\frac{1}{2}(A + B) = 52° 45'\ 0''$	
$A + B = 105\ 30$	Sum $= 64°\ 6' 37'' = A$.	
$\frac{1}{2}(A + B) = 52\ 45$	Diff. $= 41° 23' 23'' = B$.	

Having found $\frac{1}{2}(A - B)$ by the above, we are enabled to find both A and B, as we have their half-sum and their half-difference.

Then
$\frac{1}{2}(A - B) + \frac{1}{2}(A + B) =$ larger angle
$\frac{1}{2}(A + B) - \frac{1}{2}(A - B) =$ smaller angle.

The larger angle will be opposite the larger side and the smaller angle opposite the smaller side, thus $A = 64° 6' 37''$, $B = 41° 23' 23''$.

The third side c is then found by the Sine Rule :—

$$\frac{c}{\sin C} = \frac{b}{\sin B}, \quad \therefore c = \frac{\sin C \times b}{\sin B}.$$

i.e., $\log c = \log \sin C + \log b + \log \operatorname{cosec} B$.

$C = 74° 30'$	sin 9·983911
$b = 122$	log 2·086360
$B = 41° 23' 23''$	cosec 10·179682
$c = 177·8$	log 22·249953 (reject 20)

$\therefore c = 177·8$.

Worked Example 5.

In triangle $A\ B\ C$ (Fig. 18), given angle $B = 38°\ 0'\ 0''$, side $c = 177$, side $a = 104$, to find C and A and side b.

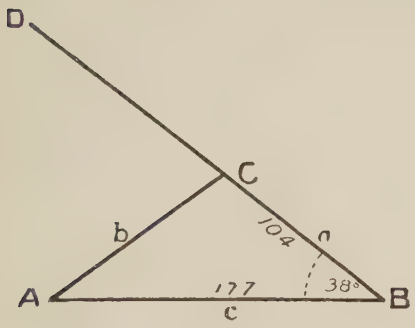


Fig. 18.

Construction.—Draw a line = 177 to any convenient scale = c or $A\ B$, make angle $A\ B\ D = 38° = B$, from B on $B\ D$ make $B\ C = 104 = a$, join $A\ C$, and it will be the required triangle.

Formula :—

$$\frac{\tan \frac{1}{2}(C - A)}{\tan \frac{1}{2}(C + A)} = \frac{c - a}{c + a},$$

$$\therefore \quad \tan \tfrac{1}{2}(C - A) = \frac{\tan \frac{1}{2}(C + A) \times c - a}{c + a},$$

i.e., $\log \tan \frac{1}{2}(C - A) = \log \tan \frac{1}{2}(C + A) + \log (c - a) - \log (c + a)$.

$c = 177$	$\frac{1}{2}(C + A) = 71°\ 0'\ 0''$	log tan	= 10·463028
$a = 104$	$c - a = 73$	log	= 1·863323
$c + a = 281$			12·326351
$c - a = 73$	$c + a = 281$	log	= 2·448706
$B = 38°$	$\frac{1}{2}(C - A) = 37°\ 2'\ 1''$	log tan	= 9·877645
180	$\frac{1}{2}(C + A) = 71\ 0\ 0$		
$C + A = 142$	Sum = 108° 2′ 1″		
$\frac{1}{2}(C + A) = 71°$	Diff. = 33° 57′ 59″		

As angle C is opposite the larger side c

$\therefore \quad C = \frac{1}{2}(C - A) + \frac{1}{2}(C + A) = 108°\ 2'\ 1''$

Angle A is opposite the smaller side a.

$\therefore \quad A = \frac{1}{2}(C + A) - \frac{1}{2}(C - A) = 33°\ 57'\ 59''$.

To find side b :—

$$\frac{b}{\sin B} = \frac{a}{\sin A}, \quad \therefore b = \frac{\sin B \times a}{\sin A},$$

i.e., $\log b = \log \sin B + \log a + \log \operatorname{cosec} A$.

$B = 38°\ 0'\ 0''$	log sin	=	9·789342
$a = 104$	log	=	2·017033
$A = 33°\ 57'\ 59''$	log cosec	=	10·252816
$b = 114{\cdot}6$	log	=	22·059191 (reject 20)

$\therefore\ b = 114{\cdot}6.$

Worked Example 6.

Case 4.—When the three sides of a triangle are given and no angles, to find the angles.

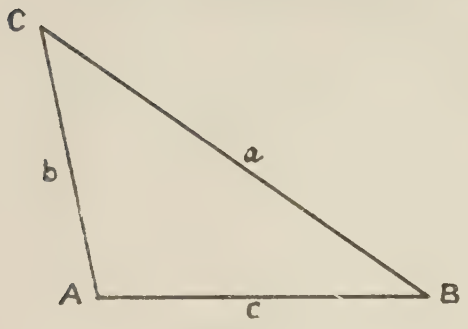


Fig. 19.

Worked Example.—In triangle $A\,B\,C$ (Fig. 19), given $a = 512$, $b = 306$, $c = 358$, to find angles A, B, and C.

Construction.—Draw any side first; in this case we have taken $c = A\,B$, then with B as centre and "a" as radius = 512 in the compasses describe an arc. With A as centre and "b" as radius = 306 describe another arc cutting the former arc at C, join $C\,A$, and $C\,B$, then $A\,B\,C$ will be the triangle.

The formulæ used in finding the angles are as follows; to find A: —

Haversine $A = \dfrac{(s-b)\,(s-c)}{b\;c}$, where s = half the sum of the sides = $\frac{1}{2}\,(a+b+c)$.

$a = 512$
$b = 306$
$c = 358$
$2)1176$
$s = 588$
$s - a = 76$
$s - b = 282$
$s - c = 230$

$\log = 2{\cdot}485721$
$\log = 2{\cdot}553883$
$5{\cdot}039604$

$\log = 2{\cdot}450249$
$\log = 2{\cdot}361728$
$4{\cdot}811977$
$- 5{\cdot}039604$
hav. $= 9{\cdot}772373$

$A = 100°\ 36'\ 37''$

To find B: — Hav. $B = \dfrac{(s-a)\,(s-c)}{a\;c}$, where $s = \frac{1}{2}\,(a+b+c)$.

$a = 512$
$c = 358$
$s - a = 76$
$s - c = 230$

$\log = 2{\cdot}709270$
$\log = 2{\cdot}553883$
$5{\cdot}263153$
$\log = 1{\cdot}880814$
$\log = 2{\cdot}361728$
$4{\cdot}242542$
$- 5{\cdot}263153$
hav. $= 8{\cdot}979389$

$B = 35°\ 58'\ 30''$
$C = 180° - (A + B)$
$A = 100°\ 36'\ 37''$
$B = 35\ 58\ 30$
$136°\ 35'\ 7''$
$180\ 0\ 0$
$\therefore\quad C = 43°\ 24'\ 53''$

Angle $A = 100°\ 36'\ 37''$
Angle $B = 35\ 58\ 30$
Angle $C = 43\ 24\ 53$

WORKED EXAMPLE 7.

Fig. 20. In triangle $A\,B\,C$, given $a = 500$, $b = 528$, $c = 420$, to find the angles.

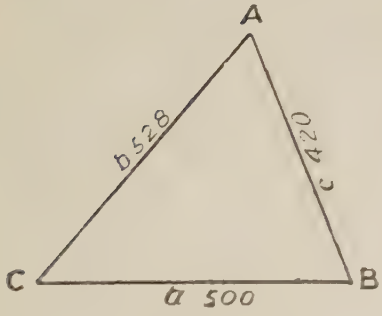


Fig. 20.

To find A :—Haversine $A = \dfrac{(s-b)(s-c)}{b\,c}$.

$a = 500$		
$b = 528$	log	$= 2{\cdot}722634$
$c = 420$	log	$= 2{\cdot}623249$
$1{,}448$		$5{\cdot}345883$
$s = 724$		
$s - a = 224$		
$s - b = 196$	log	$= 2{\cdot}292256$
$s - c = 304$	log	$= 2{\cdot}482874$
		$4{\cdot}775130$
		$-\ 5{\cdot}345883$
$A = 62°\ 26'\ 36''$	hav.	$= 9{\cdot}429247$

To find B :— Haversine $B = \dfrac{(s-a)(s-c)}{a\,c}$.

$a = 500$	log	$= 2{\cdot}698970$
$c = 420$	log	$= 2{\cdot}623249$
		$5{\cdot}322219$
$s - a = 224$	log	$= 2{\cdot}350248$
$s - c = 304$	log	$= 2{\cdot}482874$
		$4{\cdot}833122$
		$-\ 5{\cdot}322219$
$B = 69°\ 25'\ 22''$	hav.	$= 9{\cdot}510903$

Angle $C = 180 - (A + B)$.

A	$= 62°$	$26'$	$36''$
B	$= 69$	25	22
	$131°$	$51'$	$58''$
	180	0	0
$\therefore\ C$	$= 48°$	$8'$	$2''$

In cases where the three sides are of small values it is often more convenient to solve the triangle without the use of logarithms. For example, let the sides in a triangle be $a = 6$, $b = 10$, $c = 12$, to find angle A, we have :—

$$\text{Hav. } A = \frac{(s-b)(s-c)}{b\,c} = \frac{4 \times 2}{10 \times 12} = \frac{1}{15}.$$

$a = 6$
$b = 10$
$c = 12$
$2)\overline{28}$
$s = 14$
$s - b = 4$
$s - c = 2$

$$\text{Hav. } A = \frac{1}{15} = {\cdot}06666.$$

Natural Hav. $0{\cdot}06666$ gives $29°\ 55'\ 30''$.

$\therefore$ Angle $A = 29°\ 55'\ 30''$.

PROBLEMS IN OBLIQUE-ANGLED PLANE TRIGONOMETRY.

Worked Example I.

A tower and a lighthouse are exactly 6 miles apart. If a man saw the lighthouse bearing S.S.W. distant 5 miles when the tower bore S.E., find the bearing of the latter from the lighthouse and its distance from the observer.

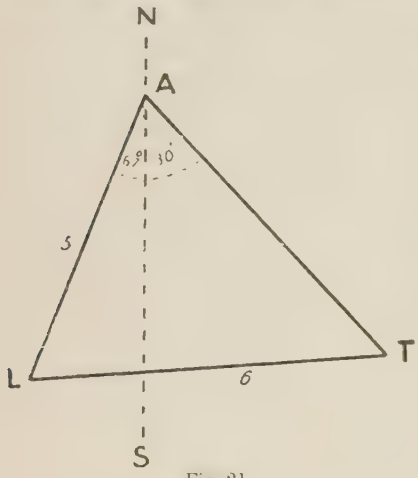


Fig. 21.

Construction.—Draw the N. and S. line and anywhere on the northern part of it, let A be the position of the man. Lay off the bearing of the lighthouse S.S.W. and the bearing of tower S.E. Make $A\,L = 5$, then L is the position of lighthouse, with L as centre and 6 in the compasses make an arc cutting the bearing of the tower at T, join $L\,T$, then $A\,L\,T$ is the triangle. Angle A = difference between bearings $= 67°\ 30'$. Then in triangle $A\,L\,T$, we have side $A\,L = 5$, side $L\,T = 6$, angle $A = 67°\ 30'$ opposite greater side, so that we must first find angle T by the **"rule of sines."**

$$i.e., \quad \frac{\sin T}{A\,L} = \frac{\sin A}{L\,T}.$$

$$\therefore \quad \sin T = \frac{A\,L \times \sin A}{L\,T}.$$

Side $A\,L = 5$	log =	0·698970
Angle $A = 67°\ 30'$	sin =	9·965615
		10·664585
Side $L\,T = 6$	log —	0·778151
Angle $T = 50°\ 20'\ 42''$	sin =	9·886434

Angle T =	50° 20′ 42″
A =	67 30 0
	117° 50′ 42″
	180 0 0
L =	62° 9′ 18″

To find bearing of T from L.

Direction of $L\,A$ = N. 22° 30′ 6″ E.
Angle L = 62 9 18 to right
Bearing of T from L = N. 84° 39′ 18″ E.

To find $A\,T$ the distance of observer from the tower.

$$\frac{A\,T}{\sin L} = \frac{L\,T}{\sin A} \quad \therefore A\,T = \frac{\sin L \times L\,T}{\sin A}.$$

Angle $L = 62°\ 9'\ 18''$	L sin	= 9·946558
Side $L\,T = 6'$	log	= 0·778151
Angle $A = 67°\ 30'\ 0''$	L cosec	= 10·034385
Side $A\,T = 5{\cdot}74$	log	= 0·759094

Bearing of tower from lighthouse = N. 84° 39′ 18″ E.
Distance of tower from observer = 5·74 miles.

Worked Example 2.

A steamer was observed from the shore bearing N. 40° E., the angle between her truck and the waterline was 1° 0′; later when she was bearing S. 40° E. the angle between the truck and waterline had increased to 1° 30′. Find the course the ship was steering.

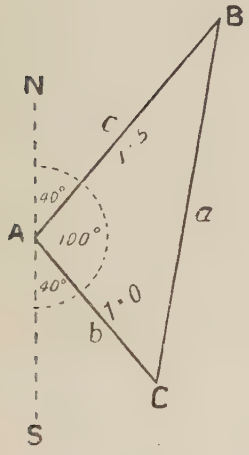


Fig. 22.

Fig. 22. Let A be the position of observer, B the ship at first observation, and C the ship at the second observation. Then angle $N\,A\,B = 40°$ and $S\,A\,C = 40°$. As the altitudes of the same height are in the same ratio as the distances from the object, inversely; we can make $A\,B = 1{\cdot}5$ and $A\,C = 1{\cdot}0$, and with these two ratios as sides and the contained angle $B\,A\,C$ we can find angle B and thence the course.

In triangle $A\,B\,C$, given $A = 100°$, $A\,B = 1{\cdot}5$, $A\,C = 1{\cdot}0$, to find angle B.

Formula :—

$$\frac{\tan\frac{1}{2}(C-B)}{\tan\frac{1}{2}(C+B)} = \frac{c-b}{c+b},\ \therefore \tan\tfrac{1}{2}(C-B) = \frac{\tan\frac{1}{2}(C+B)\times c-b}{c+b}.$$

$(C+B)$	$= 180° - A$	
$(C+B)$	$= 80°$	
$\frac{1}{2}(C+B)$	$= 40°$	$\tan$ 9·923814
$c-b$	$= {\cdot}5$	$\log$ 9·698970
		9·622784
$c+b$	$= 2{\cdot}5$	$\log$ 0·397940
$\frac{1}{2}(C-B)$	$= 9° 31' 35''$	$\tan$ 9·224844
$\frac{1}{2}(C+B)$	$= 40° 0' 0'$	
Sum	$= 49° 31' 35'' = C$	
Diff.	$= 30° 28' 25'' = B.$	

To find the course :—

Direction of line $B\,A$ = S. 40° 0′ 0″ W.
Angle B = 30 28 25 (to the left)
Ship's course S. 9° 31′ 35″ W.

Worked Example 3.

A steamer steering to the Westward sights a lighthouse bearing N. 26° W. distant 5 miles. She proceeds 5·5 miles along her course and the lighthouse is then distant 4·2 miles. What course was she steering ?

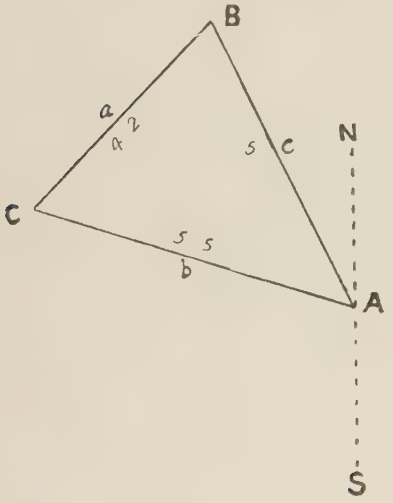


Fig. 23.

Construction.—Let A be the first position of steamer. Make angle $N\,A\,B = 26°$ and $A\,B = 5$, then B will be the position of lighthouse. With A as centre and 5·5 as radius describe an arc, and with B as centre and 4·2 as radius describe another arc cutting the former arc in C. Then $A\,B\,C$ is the triangle required, we must find angle $B\,A\,C$ and thence angle $N\,A\,C$ = course.

In triangle $A\,B\,C$, given $A\,B = 5$, $A\,C = 5·5$, $B\,C = 4·2$, to find A.

Formula :—Haversine $A = \dfrac{(s-b)\,(s-c)}{b\,c}$.

where $s = \frac{1}{2}$ sum of sides.

a	$= 4·2$		
b	$= 5·5$	log	$= 0·740363$
c	$= 5·0$	log	$= 0·698970$
	$2)\overline{14·7}$		$\overline{1·439333}$
s	$= 7·35$		
$s-b$	$= 1·85$	log	$= 0·267172$
$s-c$	$= 2·35$	log	$= 0·371068$
			$0·638240$
			$-\ 1·439333$
A	$= 46°\ 51'\ 22''$	$\angle$ hav.	$9·198907$

To find the course :—

Direction of $A\,B$ = N.	$26°\ 0'\ 0''$	W.
Angle A +	$46°\ 51'\ 22''$	
Course	= N. $72°\ 51'\ 22''$	W.

Without logs :—

$$\text{Hav. } A = \frac{(s-b)\,(s-c)}{b\,c} = \frac{1·85 \times 2·35}{5·5 \times 5}.$$

Hav. $A = 0·1581$.

$\therefore A = 46°\ 51'\ 30''$.

Worked Example 4.

A vessel is moored in a position equidistant from three buoys, A, B, and C. Find the course and distance she would have to steam from A to take up this position, supposing A to be due East, 7 miles from B, and C to be 8 miles from B and 9 miles from A, C being North of A and B.

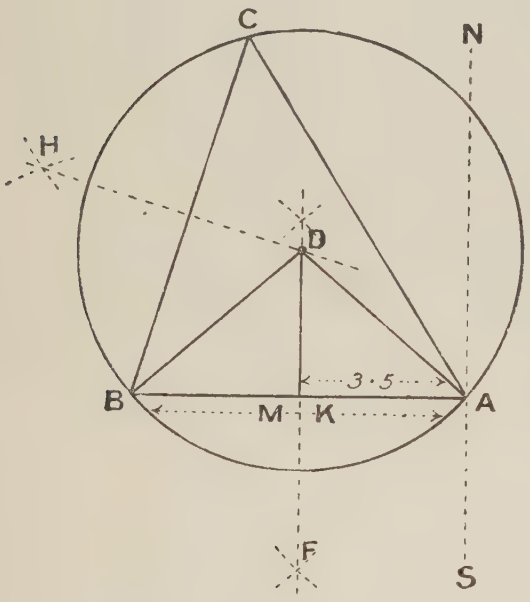


Fig. 24.

Construction.—Construct the triangle $A\,B\,C$ as described in Worked Example 3, making $A\,B = 7$, $B\,C = 8$, $A\,C = 9$. As the vessel is equidistant from each buoy she must be at the centre of a circle passing through A, B, and C. To describe this circle bisect the line $A\,B$ by the line $F\,D$ and the line $B\,C$ by the line $H\,D$; where the two bisecting lines meet at D is the centre of the required circle. With centre D and radius $D\,A$ or $D\,B$ describe the circle. Join $D\,A$ and $D\,B$. In order to find the course from A to the centre of the circle we must first find angle C.

In triangle $A\,B\,C$, given the three sides, to find angle C.

Formula :—Hav. $C = \dfrac{(s-a)(s-b)}{a\,b}$.

where $s = \frac{1}{2}(a+b+c)$.

$a = 8$
$b = 9$
$c = 7$

$2)\overline{24}$

$s = 12$

$s - a = 4$

$s - b = 3$

$\dfrac{4 \times 3}{8 \times 9} = \dfrac{1}{6} = \cdot 16666,$

$\therefore$ Hav. $C = \cdot 16666$

$C = 48^\circ\ 11'\ 15''$

In the figure, angle $A\,C\,B$ is an angle in the circumference and angle $A\,D\,B$ an angle at the centre of the circle subtended by the same arc $A\,B$, therefore angle $A\,D\,B$ is twice angle $A\,C\,B$ (see elements of geometry); also angle $A\,D\,F$, being half of $A\,D\,B$, is equal to $A\,C\,B$. $N\,A\,D$ is the course to steer from A to D, and by parallels angle $N\,A\,D$ is equal to $A\,D\,F$, which is again equal to $A\,C\,B$.

$\therefore$ **Course from A to D = N. 48° 11′ 15″ W.**

In R.A. triangle $A\,D\,K$, given angle D and side $A\,K = 3{\cdot}5$, to find $A\,D$ = distance to steam.

$$\frac{A\,D}{K\,A} = \text{cosec } D \ \therefore\ A\,D = K\,A \times \text{cosec } D.$$

$K\,A$	$= 3{\cdot}5$	log	0·544068
D	$= 48^\circ\ 11'\ 15''$	cosec	10·127651
$A\,D$	$= 4{\cdot}69$	log	10·671719

Distance to steam = 4·69 miles.

Worked Example 5.

A cruiser receives a message that an enemy vessel bearing N.W. distant 36 miles is steering S. 60° W. at a speed of 18 knots. What course must the cruiser steer to intercept the enemy craft at a speed of 24 knots, and how long would it take her to do so?

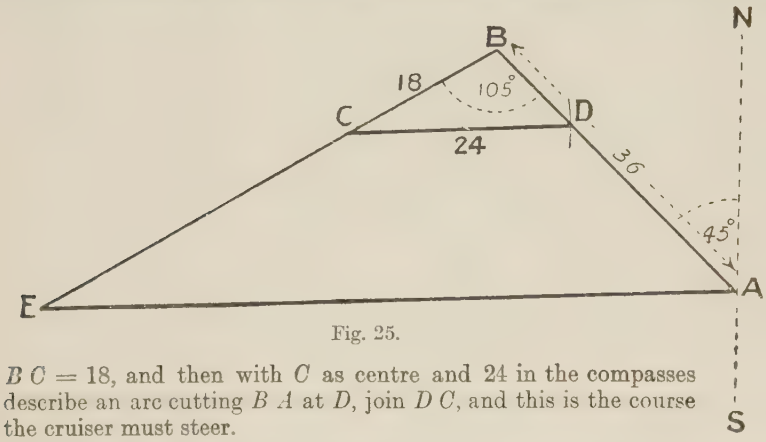


Fig. 25.

Construction.—Let A be the position of the cruiser on the N. and S. line, make angle $N\,A\,B = 45°$ and $A\,B = 36$, then B is the position of the enemy vessel. The direction of $B\,A$ is S. 45° E., and the enemy is steering S. 60° W., so that if we make angle $A\,B\,C = 105°$ $B\,C$ is the course of the enemy. The course the cruiser must steer depends on the speeds of the two vessels, therefore, make $B\,C = 18$, and then with C as centre and 24 in the compasses describe an arc cutting $B\,A$ at D, join $D\,C$, and this is the course the cruiser must steer.

To find the distance the cruiser will have to steam, draw a line from A parallel to $D\,C$, the course line, to where this meets $B\,C$, extended at E, then $A\,E$ is the distance the cruiser will have to steam. If the same scale has been used throughout, the results from the figure will be a very good check on those obtained by calculation.

In triangle $D\,B\,C$, given $B\,C = 18$, $C\,D = 24$, angle $B = 105°$, to find angle D.

Formula :— $$\frac{\sin D}{d} = \frac{\sin B}{b},\ \therefore \sin D = \frac{d \times \sin B}{b}.$$

$$\therefore \quad \sin D = \frac{18 \times \sin B}{24} = \frac{\sin B}{1{\cdot}333}.$$

$B = 105°$	sin	9·984944
1·333	log	0·124830
D = 46° 26′ 16″	sin	9·860114

It will be seen here that we have divided 18 into 24 and thus avoided using so many logs. This can often be done with small numbers, and saves a little time.

$D\,B$ = N. 45° 0′ 0″ W.
Course N. 91° 26′ 16″ W.

In triangle $A\,B\,E$, given $A\,B = 36$, angle $B = 105°$ and angle A = angle $B\,D\,C = 46°\ 26'\ 16''$, to find $A\,E$ = distance.

$$\frac{A\,E}{\sin B} = \frac{A\,B}{\sin E},\ \therefore A\,E = \frac{\sin B \times A\,B}{\sin E}.$$

$E =$ 28° 33′ 44″	cosec	10·320470
$B =$ 105° 0′ 0″	sin	9·984944
$A\,B =$ 36	log	1·556302
Distance = 72·73	log	1·861716

$B = 105°\ 0'\ 0''$
$A = 46\ 26\ 16$
$151°\ 26'\ 16''$
$180\ 0\ 0$
$E = 28°\ 33'\ 44''$

To find the time taken.

As 24 : 72·7 :: 1 : x

24) 72·70 (3·03
72 60
·70 1·80

= 3 h. 1·8 m.

Course, N. 91° 26′ 16″ W.
180 0 0
or S. 88° 33′ 44″ W.
Time taken = 3h. 1·8m.

Worked Example 6.

An observer in a ship observes the bearing of a lighthouse to be N. 50° E. with an angular height of 1° 39′, after steaming for 3 miles it bore N. 20° W. with an angular height of 1° 22′. Find the height of the lighthouse.

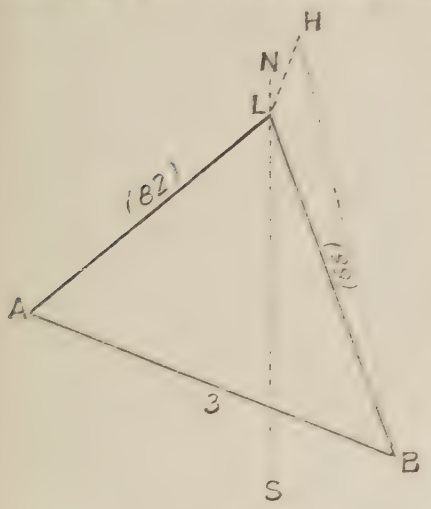


Fig. 26.

Construction.—In Fig. 26, let L represent the lighthouse on the N. and S. line. Reverse the bearings and lay them off from L. As the elevated angles are inversely proportional to the distances off the lighthouse, turn the altitudes into minutes and mark off the first altitude as the second distance off, and the second altitude of the lighthouse as the first distance off. Then $L\,A = 82$ and $L\,B = 99$. A represents the first position of the vessel and B the second position, therefore $A\,B = 3$ miles. The values of 82 and 99 are proportional, not actual distances, whilst the value of $A\,B$ must be considered as actual distance in miles. If $L\,H$ is the height of the lighthouse, then $H\,L\,B$ is a right-angled triangle where $L = 90°$ and $B = 1° 22′$.

In triangle $A\,L\,B$, given $L\,A = 82$, $L\,B = 99$, and angle $L = 70°$, to find angles A and B.

Formula $\dfrac{\tan \frac{1}{2}(A - B)}{\tan \frac{1}{2}(A + B)} = \dfrac{a - b}{a + b}$

$$\therefore \quad \tan \tfrac{1}{2}(A - B) = \frac{\tan \frac{1}{2}(A + B) \times a - b}{a + b}$$

Angle L	=	70° 0′	$\frac{1}{2}(A + B)$ =	55° 0′ 00″	tan 10·154773
		180° 0′	$a - b$ =	17	log 1·230449
$A + B$	=	2)110° 0′			
$\frac{1}{2}(A + B)$	=	55° 0′	$a + b$ =	181	11·385222
			$\frac{1}{2}(A - B)$ =	7° 38′ 23″	log 2·257679
a	=	99			
b	=	82	angle A =	62° 38′ 23″	tan 9·127543
$a - b$	=	17			
$a + b$	=	181	angle B =	47° 21′ 37″	

In triangle $A\,L\,B$, having given all the angles and side $A\,B = 3$, to find side $B\,L$.

$$\frac{B\,L}{\sin A} = \frac{A\,B}{\sin L}$$

$$\therefore \quad B\,L = \frac{\sin A \times A\,B}{\sin L}$$

In R.A. triangle $H\,L\,B$, given $L = 90°$, angle $B = 1° 22′$, side $B\,L = \dfrac{\sin A \times A\,B}{\sin L}$ to find $H\,L$.

$$\frac{H\,L}{L\,B} = \tan B, \quad \therefore H\,L = L\,B \times \tan B.$$

$$\therefore \quad H\,L = \frac{\sin A \times A\,B}{\sin L} \times \tan B$$

$$\therefore \quad H\,L = \sin A, \tan B, \operatorname{cosec} L \times A\,B$$

A = 62° 38′ 23″	sin	9·948478
B = 1 22 0	tan	8·377622
L = 70 0 0	cosec	10·027014
$A\,B$ = 3 miles	log	0·477121
$H\,L$ = ·066 mile	log	8·830235
6,080 feet	log	3·783904
$H\,L$ in feet = 411·3	log	2·614139

Height of lighthouse = 411·3 feet.

Worked Example 7.

A and B are two steamers in a convoy steering N.N.W. at 10 knots. B being 2 miles on A's starboard beam is ordered to take a position 1 mile ahead of A and to increase speed to 12 knots. Find the course that B must steer and the time it will take her to reach her new position ahead of A.

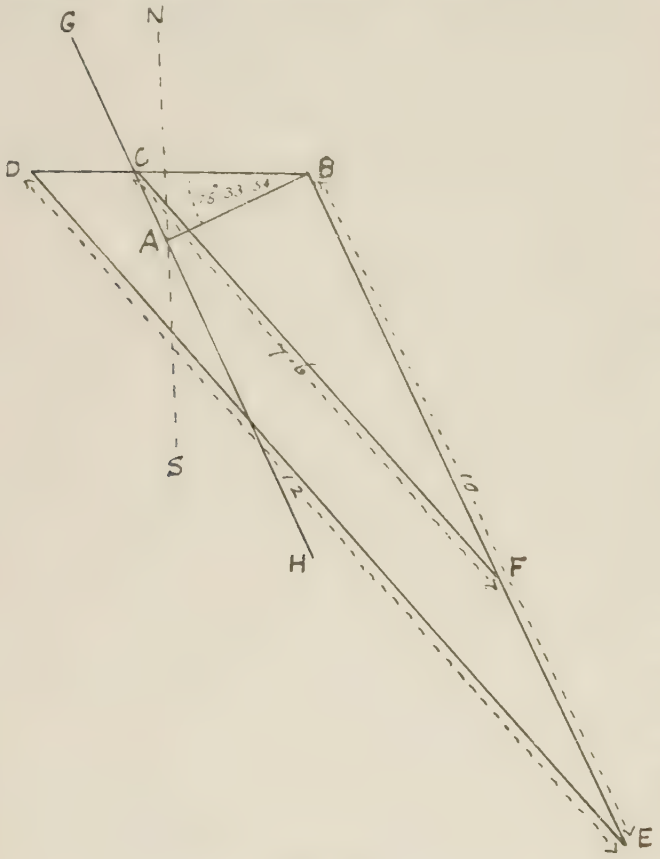


Fig. 27.

Construction.—Take any point A in the N. and S. line to represent steamer A, and make angle $N\,A\,G = 22°\ 30'$, then $A\,G$ represents A's course. Draw $A\,B$ from A perpendicular to $A\,G$ and $= 2$, and $A\,C$ on $A\,G = 1$, then B is the original position of B and C the final position of B, join $B\,C$.

If A were stationary, B would simply have to steam from B to C, but A is not, she is steaming at 10 knots. We will, therefore, assume, that A carries this line $B\,C$ ahead 10 miles, and to get this effect we will put B back 10 miles parallel to A's course by making $B\,E$ parallel to $G\,A$ and equal 10. But in the same time that A steams 10 knots B steams 12, so we must find the position on $B\,C$ or $B\,C$ extended where B would be after an hour's steaming. To do this, take 12 in the compasses, and with the point on E describe an arc cutting $B\,C$ extended at D, join $E\,D$, and make $C\,F$ parallel to $D\,E$.

Then angle $D\,E\,B$=angle $C\,F\,B$, and this will be B's alteration of course.

It must be quite clearly understood that B must approach A along the line $B\,C$ as if A were stationary, and, in order to do so with A going ahead at 10 knots and B at 12 knots, she must steer in the direction of $E\,D$ or $F\,C$.

As $B\,C$ is the amount B has to proceed along this line, $F\,C$ is evidently the distance that B must steam to get there. If B steamed the full hour, she would be at D, which is considerably on A's port bow.

Preparatory to finding B's course, we must find the value of angle $C\,B\,A$, and thence angle $D\,B\,E$.

Having obtained angle $C\,B\,A$, it is seen from the figure that $C\,B\,A - A\,B\,E = D\,B\,E$.

In right-angled triangle $A\,B\,C$, $A = 90°$, $A\,C = 1$, $A\,B = 2$. To find angle B.

$\frac{A\,C}{A\,B} = \tan B$—*i.e.*, $\frac{1}{2} = \tan B$, $\therefore$ $\tan B = \cdot 5$.

N. at tangent of angle $B = \cdot 5$, $\therefore$ $B = 26°\ 33'\ 54''$.

	Angle $C\,B\,A$ =	$26°\ 33'\ 54''$
	Angle $A\,B\,E$ =	$90\ \ 0\ \ 0$
$\therefore$	Angle $D\,B\,E$ =	$116°\ 33'\ 54''$

In triangle $D\,B\,E$, given $B\,E = 10$, $E\,D = 12$, angle $B = 116°\ 33'\ 54''$, to find angle E.

Formula $\dfrac{\sin D}{\sin B} = \dfrac{B\,E}{D\,E}$, $\therefore \sin D = \dfrac{\sin B \times B\,E}{D\,E}$.

$B\,E = 10$	log = 1·000000	**Short Method :—**
$B = 116°\ 33'\ 54''$	sin = 9·951545	$\sin D = \dfrac{\sin B \times 10}{12}$
	10·951545	
$D\,E = 12$	log − 1·079181	$\sin D = \dfrac{\sin B}{1{\cdot}2}$
$D = 48°\ 11'\ 23''$	sin = 9·872364	

$B = 116°\ 33'\ 54''$ sin	= 9·951545
1·2 log	= 0·079181
$D = 48°\ 11'\ 23''$ sin	9·872364

Angle D = 48° 11′ 23″
Angle B = 116 33 54
164° 45′ 17″
180 0 0
Angle E = 15° 14′ 43″
$\therefore$ Angle $C\,F\,B$ = 15° 14′ 43″

Direction of $F\,B$ = N. 22° 30′ W.
Angle $C\,F\,B$ = + 15° 14′ 43″ left
Course to steer = N. 37° 44′ 43″ W.

In order to find the distance $F\,C$ we must first find $B\,C$, $\therefore$ in right angled triangle $A\,B\,C$ given $A\,C = 1$, $B\,A = 2$, to find $B\,C$.

$B\,C^2 = A\,C^2 + A\,B^2$
$= 1^2 + 2^2 = 5$
$B\,C = \sqrt{5}$
$= 2{\cdot}235.$

2)5(2·235
4
42)100
84
443)1600
1329
446)27100
= 2·235

In triangle $C\,B\,F$, given $B = 116°\ 33'\ 54''$, $F = 15°\ 14'\ 43''$, $B\,C = 2{\cdot}235$, to find $F\,C$.

$\dfrac{F\,C}{B\,C} = \dfrac{\sin B}{\sin F}$ $\therefore F\,C = \dfrac{B\,C \times \sin B}{\sin F}$

$B\,C = 2{\cdot}235$	log = 0·349278
$B = 116°\ 33'\ 54''$	sin = 9·951545
$F = 15°\ 14'\ 43''$	cosec = 10·580123
$F\,C = 7{\cdot}602$	log = 0·880946

$\therefore$ Distance to steam at 12 knots = 7·6 miles.

As 12 : 7·6 :: 60 : x

$\dfrac{7{\cdot}6 \times 60}{12} = 7{\cdot}6 \times 5.$

Time taken by B = 38·0 minutes.

B's course = N. 37° 44′ 43″ W.

Examples for Exercise A.

(1) A beacon and a tower are 3 miles apart. If an observer saw the tower bearing N.N.E. distant $2\frac{1}{2}$ miles when the beacon bore N.W., find the bearing of the beacon from the tower and its distance from the observer.

(2) Two points of land in line bore N. 7° E., and after steaming N. 70° E., 7 miles, one point bears N. 36° W. and the other N. 50° W. Find the distance of the ship from the nearest point and the distance the points are apart.

(3) The observed angular height of a lighthouse was 12° 20′, and after approaching the lighthouse 160 feet the angle was found to be 48°. Find the height of the lighthouse.

(4) A vessel steaming N.E. at 12 knots sights another 10° on her starboard bow. After steaming 3 miles the other steamer was abeam on the port side, and after steaming another 2 miles she was 30° on the port quarter with masts in line. What was her speed ?

(5) A steamer is observed from the shore bearing S. 40° E., the angle between the truck and the water line was 1° 30′, later she was observed from the shore bearing S. 85° E., when the angle between the truck and the water line was 2° 10′. Find the course the ship was steering.

(6) A sailing ship close-hauled on the port tack, with the wind N. by E., sights a point of land bearing North ; she continues on her course for 6 miles, then goes about. Find the distance the ship has sailed and the distance she has made good towards the point of land, when the point of land bears North, on her 2nd course (allowing 6 points to the wind).

(7) A vessel steaming along the shore observes a conspicuous object bearing N. 60° E., which subtends a vertical angle of 1° 56. After steaming 4 miles the object subtends an angle of 1° 34′ bearing N. 1° W. Find the course the ship was steering and the distance from the object at the 2nd bearing.

(8) A steamer steering to the Eastward sights a point of land bearing N. 16° E., distance 4·8 miles. She proceeds for 6 miles along her course and the point is then distant 6·4 miles. What course was she steering ?

(9) Three buoys were each 2 miles apart, *A*, *B*, and *C*. A ship is moored in the triangle formed by them ; from the ship *A* and *B* subtended an angle of 90°, and the angles subtended by *A* and *C* and *B* and *C* were equal. Find the distance of the ship from *C*.

(10) From a vessel two headlands were in line bearing N.N.E., the nearer one was distant 4 miles, and the distance between them was 9 miles. The course was then set so that the horizontal angle between them should not be more than 90°. Find the course steered, the distance steamed, when the maximum angle was reached, and the vessel's distance from each headland at that time.

(11) Two vessels *A* and *B* were sailing in convoy, *B* has orders to maintain a distance of 3 cables on *A*'s starboard beam, the height of *A*'s truck above the water line was 120 feet, and the height at *B*'s bridge deck above the water line was 40 feet, find the angle to set the sextant at in order to maintain the distance off ; allowing 5 feet 6 inches for the height of eye above the bridge deck.

(12) The perimeter of a triangle is 33 miles, the sides being 14, 10, and 9 miles, and its longest side runs S.E. and N.W. Find the courses a yacht will have to steer to go round it right-handedly, the sides being taken in the order they are given.

(13) Two ships meeting end on, both alter course 2 points to starboard, each steaming 10 knots. After steaming 6 minutes they were 4 points on each other's port bow, and they returned to their original courses. How far did they pass off each other ?

(14) A ship was anchored S. 25° W. from a lighthouse, distant 4 miles. She was ordered to take up a position S. 40° E., distant 3 miles from the lighthouse. Find her course and distance to steam.

(15) A point A is 1·6 miles N.W. of B, and C is 1·2 miles from A and 1·1 miles from B. Find the bearings of A and B from C, taking C to be south and west of A.

(16) A ship has two objects in transit 7 points on port bow, and after running 5 miles the nearest object is 4 points abaft the beam and the angle between the objects 18°. Find the distance between the objects.

(17) A vessel A sights another vessel B right ahead crossing her course, the elevated angle of her mast being 1° 52′. A quarter of an hour after A is right astern of B, with B two points abaft the starboard beam, the angular height of B's mast now being 1° 36′. Find the speed of B if A's speed was 8 knots.

(18) A warship receives information that an enemy ship is bearing N.N.W. from him and distant 30 miles, steering W.S.W. at 20 knots. If the warship's maximum speed is 35 knots, how long will it take him to intercept the enemy, and what course must he steer to do so ?

(19) From a vessel at anchor two beacons in the same meridian bear N. 34° W. and S. 56° W., the vertical angles subtended by these beacons are equal. Find the ratio of their heights.

(20) From a ship at sea a cliff bearing N. 3° E. subtends a vertical angle at 0° 42′, and another cliff of equal height bearing N. 20° W. subtends an angle of 0° 54′. Find the distance of the ship from each of the cliffs if their distance apart is 3·6 miles.

(21) Two ships A and B sailed from the same point. A's course, N. 40° E., speed 8 knots ; B's course, S. 70° E., speed 10 knots. How far apart are they at the end of one hour ?

(22) A and B, two steamers, steamed for one hour at 10 and 15 knots respectively. A's course was N.W. and B's course was S.W. At the commencement B bore North from A distant 10 miles. What was the bearing and distance of B from A at the end of the hour's run ?

(23) A and B are two destroyers steaming North at 15 knots, B being on A's port beam distant 5 miles has orders to take a position 2 miles astern of A, and to be in this position in 15 minutes. Find the course that B must steer and the speed she must steam at to carry out the order.

(24) Three buoys are 4, 6, and 7 cables apart, and a vessel is moored between them and equidistant from each buoy. How far was the vessel from the buoys ?

SPHERICAL TRIGONOMETRY.

DEFINITIONS.

DEF. 1.—Great circles are those whose plane passes through the centre of the sphere, thus dividing it into two equal parts.

DEF. 2.—Small circles are those whose planes do not pass through the centre of the sphere, thus dividing it into two unequal parts.

DEF. 3.—A spherical angle is the point of intersection of two great circles or the angle between the planes of two great circles.

DEF. 4. -A spherical triangle on the surface of a sphere is the triangle formed by the arcs of three great circles, each side is thus less than a semicircle, and each angle opposite any side less than two right angles.

DEF. 5.—The distance between any two points on the surface of a sphere is an arc of the great circle between the points, and is expressed in arc by degrees, minutes, and seconds—*i.e.* (° ′ ″), for this reason the sides of spherical triangles are also expressed in (° ′ ″).

DEF. 6.—A right-angled spherical triangle has one of its angles equal to 90°.

DEF. 7.—A quadrantal triangle is one that has a side the arc of which is 90° or half a semicircle, which is a quadrant.

DEF. 8.—Two arcs are of the same affection when both are less or greater than a quadrant or 90°, and similarly two angles are of the same affection when both are less or greater than 90°.

DEF. 9.—Two arcs or angles of a spherical triangle are said to be of unlike affection when one is greater and one is less than 90°.

DEF. 10.—In all spherical triangles the sines of the angles are proportional to the sines of their opposite sides.

DEF. 11.—The sum of the angles of any spherical triangle is more than two right angles and less than four right angles.

DEF. 12.—In any spherical triangle, any one side is less than the sum of the other two sides.

DEF. 13.—In any spherical triangle the sum of the three sides is less than four quadrants or a great circle or four right angles.

RIGHT-ANGLED SPHERICAL TRIGONOMETRY.

I. In any R.A. spherical triangle when **two sides** are of the **same affection** the **third side** is **less** than 90°, and when **two sides** are of **unlike affection** the **third side** is **more** than 90°.

II. In any R.A. spherical triangle (omitting right angle) an **angle** and its **opposite** side are always of the **same affection**, and if the angle is acute the side is smaller than the angle, and if obtuse the side is larger than its opposite angle.

III. The **hypotenuse** and **any side** are of the **same affection** when the **included angle is acute**, and of **unlike affection** when the **included angle** is **obtuse.**

As the above is of the greatest importance in the solution of R.A. spherical triangles, the student should prove their accuracy for himself by getting a sphere of any description, and drawing on it two great circles at right angles to each other and another great circle at right angles to each of these two ; he will then have divided the surface of the sphere into right equal R.A. triangles, and by drawing any other great circles, cutting these obliquely, on the sphere he can obtain graphical proof of the above statements.

Napier's Rules for Circular Parts.

In a R.A. spherical triangle, if the right angle be ignored, there will remain five parts—*i.e.*, two angles, the two sides that include the right angle, and the hypotenuse. Now, if we take the two sides that contain the right angle, the complements of the two angles and the complement of the hypotenuse as the **five circular parts**, then **any three** of these parts being taken, one part will be either **between** the other two parts or **opposite** the other two parts.

For example, in R.A. spherical triangle $A\,B\,C$ (Fig. 28), $A = 90°$, then the **five circular parts** are :—c, b, comp C, comp a, and comp B, and if these parts be placed in the form of a circle, as in Fig. 29, we shall see at once that whichever three parts are taken, one of these parts will be either between or opposite the other two parts, when one part is between two other parts they are said to be **adjacent** to it.

From this we get by Napier's Rules the two formulæ :—

Sine of Middle Part = { Product of **Tangents** of **Adjacent** parts. / Product of **Cosines** of **Opposite** parts.

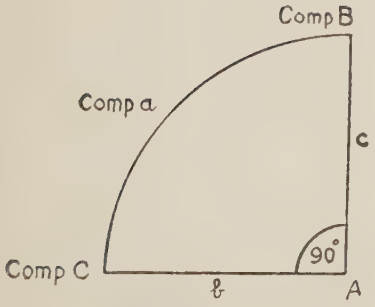


Fig. 28.

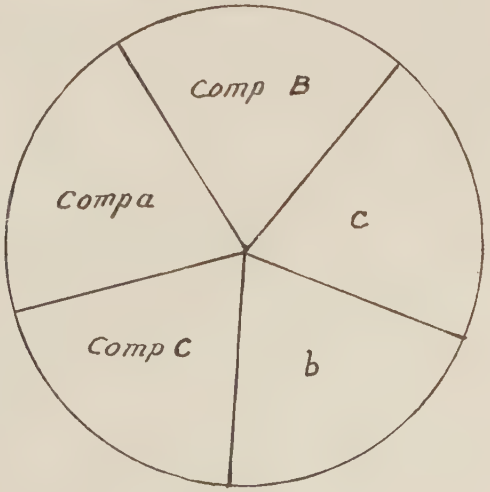


Fig. 29.

It will be seen from the foregoing that if any two parts are given we can find the third, for if the two given parts are not adjacent we can find the part between them, and if the two given parts are adjacent we can find the part opposite them. For example, suppose we have given C and c in $A\ B\ C$, Fig. 28, by referring to Fig. 29 we see that b is between c and C, and therefore

$$\sin b = \text{tangent comp } C \times \text{tangent } c$$

i.e.,
$$\sin b = \text{cotan } C \times \tan c.$$

The middle part must always be written down first.

Again, in the same triangle, suppose we are given a and B, we see by Fig. 29 that comp a and comp B are adjoining and that b is opposite to both of them, therefore

$$\sin b = \text{cosine comp } a \times \text{cosine comp } B$$

i.e.,
$$\sin b = \sin a \times \sin B.$$

It is a good idea when deducing the formula, to mark the parts you are considering with a cross ($\times$).

It must be carefully remembered that :—

Tangent comp A = cotan A.
Sine comp A = cosine A.
Cotan comp A = tan A.
Cosine comp A = sine A.

Example 1.—In triangle $A\ B\ C$ (Fig. 28), given B and a, to find C. Referring to Fig. 29, we find the three parts are adjacent, and by always taking the middle part first, we get

$$\text{Sin comp } a = \tan \text{ comp } B \times \tan \text{ comp } C$$
$$= \cos a \quad = \cot B \cot C.$$

As we require C, we must have C on one side of the equation by transposing cot B—*i.e.*,

$$\frac{\cos a}{\cot B} = \cot C.$$

By using the reciprocal of cot B, we get

$$\cos a \times \tan B = \cot C.$$

i.e., $\log \cos a + \log \tan B = \log \cot C.$

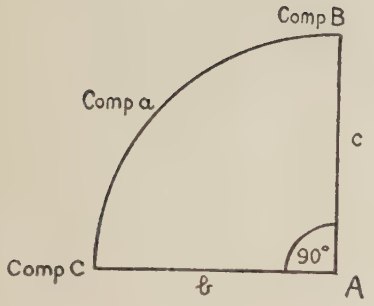


Fig. 28.

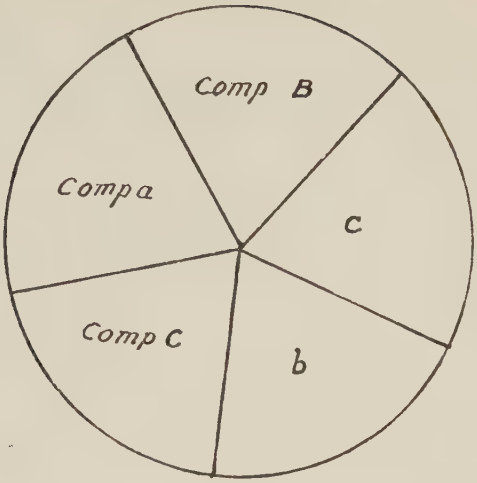


Fig. 29.

EXAMPLE 2.—Again in triangle $A\ B\ C$, given a and c, to find C.

By referring to Fig. 29, we see that c is opposite a and C, therefore

$$\sin c = \cos \text{comp } a \times \cos \text{comp } C$$

i.e.,
$$\sin c = \sin a \times \sin C$$

$$\frac{\sin c}{\sin a} = \sin C,$$

or
$$\sin c, \text{ cosec } a = \sin C$$

i.e.,
$$\log \sin c + \log \text{cosec } a = \log \sin C.$$

EXAMPLE 3.—Again in triangle $A\ B\ C$, given a and C, to find b.

The three parts being adjacent or together, we have

$$\text{Sin comp } C = \tan \text{comp } a \times \tan b$$

$$\cos C = \cot a \times \tan b$$

$$\cos C, \tan a = \tan b$$

$\therefore$
$$\log \cos C + \log \tan a = \log \tan b.$$

EXAMPLE 4.—In the same triangle, given a and b, to find c.

The parts being opposite, we have

$$\text{Sin comp } a = \cos b \times \cos c$$

$$\cos a = \cos b \times \cos c$$

i.e.,
$$\cos a, \text{ secant } b = \cos c.$$

$$\log \text{ cosine } a + \log \text{ secant } b = \log \text{ cosine } c.$$

EXAMPLE 5.—In the same triangle, given C and B, to find c.

C being opposite B and c, we have

$$\text{Sin comp } C = \cos \text{comp } B \cos c$$

i.e.,
$$\cos C = \sin B \cos c$$

$$\cos C, \text{ cosec } B = \cos c$$

$\therefore$
$$\log \text{ cosine } C + \log \text{ cosec } B = \log \text{ cosine } c.$$

It will be noticed from the above that when transposing a ratio from one side of an equation to another we use the reciprocal, as this does away with the necessity of dividing by the ratio, and thus makes the logs additive.

THE AMBIGUOUS CASE.

In any right-angled spherical triangle, when an angle (other than the right angle) and its opposite side are given, two triangles can be constructed from these given parts.

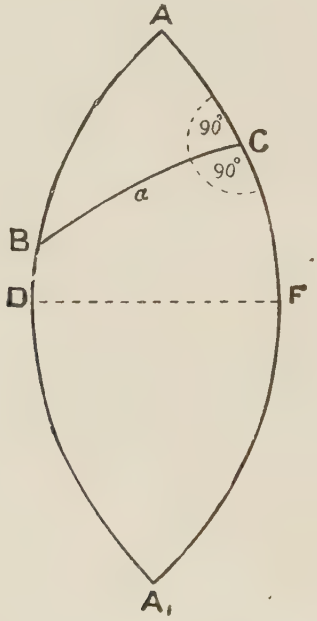


Fig. 30.

Thus, in Fig. 30, right-angled at C, if we are given angle A and the side a opposite to it; both triangles $A\ B\ C$ and $A_1 B\ C$ have the same values of A and a, and thus either of them gives a solution of the triangle; also $A\ B$ and $A\ C$ are supplements of $A_1 B$ and $A_1 C$, and angles $A\ C\ B$ and $A\ B\ C$ are supplements of angles $A_1 C\ B$ and $A_1 B\ C$. When angle A is equal to a, as in triangle $A\ D\ F$, then it will be seen there can be only one triangle in the solution, as $A\ D\ F = A_1 D\ F$ and $A\ D = A_1 D$ and $A_1 F = A\ F$, and each are 90°; also angles D and F are each 90°, as A is the pole of $D\ F$. When angle A and its opposite side "a" are each of 90°, then "b" and B are indeterminate, for B then is the pole of $A\ C$, so that B and b are equal, but may be of any value.

A **quadrantal spherical triangle** is solved in precisely the same way as a right-angled spherical triangle, except that in the case of a quadrantal triangle the five circular parts are the two adjacent or adjoining angles of the quadrant or side = 90° and the complements of the remaining two sides and angle. The side that is 90° is omitted in the same manner that the right angle is omitted in R.A. spherical triangles.

WORKED EXAMPLES OF R.A. AND QUADRANTAL SPHERICAL TRIANGLES.

EXAMPLE 1.—In the R.A. spherical triangle $A\,B\,C$, $A = 90°$, $b = 87°\ 20'$, $c = 81°\ 20'$; to find angles B amd C and side a.

In Fig. 31, let $A\,B\,C$ be the triangle, then the five circular parts in Napier's Rules are b, c, complement B, complement a, and complement C. By placing these parts in the form of a circle, as in Fig. 29, we obtain the following :—

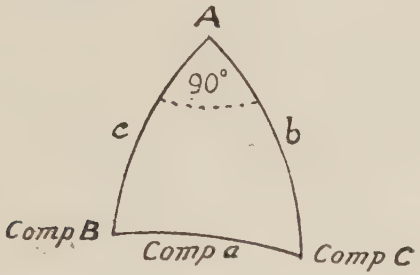


Fig. 31.

To find a :—

As a is opposite to b and c.

$$\sin \text{comp } a = \cos b \times \cos c.$$
$$\cos a = \cos b \times \cos c.$$

$b = 87°\ 20'$	$\cos\ 8{\cdot}667689$
$c = 81°\ 20'$	$\cos\ 9{\cdot}178072$
$a = 89°\ 35'\ 54''$	$\cos\ 7{\cdot}845761$

To find C :—

C, b, and c are adjacent, taking the middle part first :—

$$\sin b = \tan c \times \tan \text{comp } C.$$
$$\therefore \sin b \times \cot c = \cot C.$$

$b = 87°\ 20'$ sin	$= 9{\cdot}999529$
$c = 81°\ 20'$ cot	$= 9{\cdot}183059$
$C = 81°\ 20'\ 34''$	cot $= 9{\cdot}182588$

To find B :—

B, c, and b being adjacent, we have

$$\sin c = \tan b, \tan \text{comp } B.$$
$$\therefore \sin c \times \cot b = \cot B.$$

$b = 87°\ 20'$	cot $= 8{\cdot}668160$
$c = 81°\ 20'$	sin $= 9{\cdot}995013$
$B = 87°\ 21'\ 50''$	cot $= 8{\cdot}663173$

Therefore,

$$a = 89°\ 35'\ 54''$$
$$B = 87\ \ 21\ \ 50$$
$$C = 81\ \ 20\ \ 34$$

When you have had a little practice you should be able to solve these problems by making the triangle only. It will then not be necessary to draw the circle.

Worked Example 2.

In right-angled spherical triangle $A\ B\ C$, given $A = 90°$, $b = 110°\ 19'$, $C = 112°\ 18'$; to find a, B, and c.

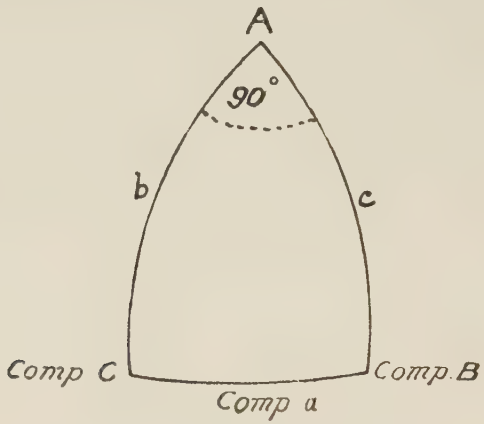


Fig. 32.

In triangle $A\ B\ C$ (Fig. 32) we have angle $C = 112°\ 18'$ and $b = 110°\ 19'$. As angles and their opposite sides are always of the same affection, the required angle B and side c will both be more than 90°; also the two sides b and c, being of the same affection, the third side a will be less than 90° (Rule I.).

To find angle B :—

Sin comp B = cos comp C, cos b.
$\therefore$ cos B = sin C, cos b.

$C = 112°\ 18'$	sin 9·966240
$b = 110°\ 19'$	cos 9·540590
$71°\ 15'\ 45''$	cos 9·506830

$B = 108°\ 44'\ 15''$

To find side c :—

Sin b = tan c, tan comp C
Sin b = tan c, cot C.
$\therefore$ Sin b, tan C = tan c.

$C = 112°\ 18'$	tan = 10·387079
$b = 110°\ 19'$	sin = 9·972105
$66°\ 22'\ 45''$	tan = 10·359184

$c = 113°\ 37'\ 15''$.

To find side a :—

Sin comp C = tan b, tan comp a
cos C = tan b, cot a
$\therefore$ cos C, cot b = cot a

$C = 112°\ 18'$	cos = 9·579162
$b = 110°\ 19'$	cot = 9·568486
$a = 82°\ 0'\ 10''$	cot = 9·147648

As B and c are each over 90°, we must take the supplements of their values as taken from the tables.

$B = 108°\ 44'\ 15''$
$c = 113\ 37\ 15$
$a = 82\ 0\ 10$

Worked Example 3.

A B C is a spherical triangle, right-angled at *C*. Side *A B* = 93°. Side *B C* = 83° 54′. Find angle *B*.

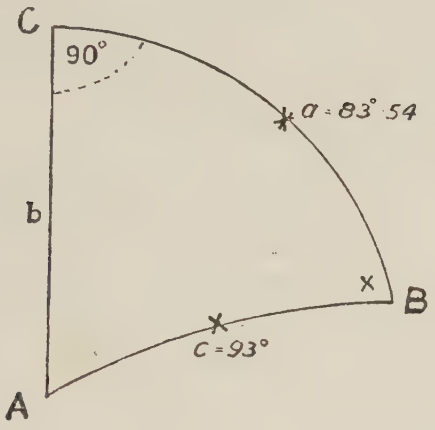


Fig. 33.

In this example the two given parts and the required part are adjacent to each other ; we, therefore, get :—

Sin middle part = product of tangents of adjacent parts.

Or sin comp B = tan a tan comp c
or cos B = tan a cot c
a = 83° 54′ tan 0·971148
c = 93 0 cot 8·719396 *

cos 9·690544 = 60° 38′
180 0

Angle B = 119° 22′

* 93° cot is the same as 3° tan ; the log tan 3° is, therefore, used.

The side opposite the right angle in this example is more than 90°. We, therefore, know that the two sides forming the right angle are of opposite affection—that is, one less and one greater than 90°.

As side a is less than 90°, we know that side b must be more than 90°. As an angle and its opposite side are always of the same affection, angle B must also be more than 90°. The value we get from the tables is, therefore, taken from 180°.

Worked Example 4.

In the quadrantal spherical triangle $A\ B\ C$, given $a = 90°$, $B = 83°\ 20'$, $c = 79°\ 56'$; required to find A, b, and C.

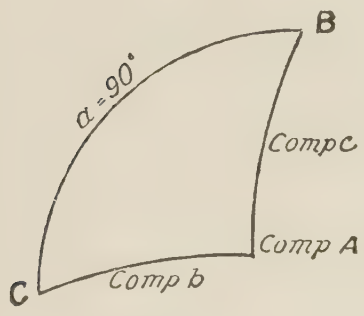


Fig. 34.

This being a quadrantal triangle, the side a, being 90°, is omitted, and thus the five circular parts are B, C, comp b, comp c, and comp A, we then proceed as in R.A. triangles.

Important.—When the two angles that are adjacent to the side = 90°, in this case B and C are of the same affection, the angle opposite the side = 90° will be over 90°, and when these two angles are of unlike affection the angle opposite the quadrant or side = 90° will be less than 90°.

In this case $B = 83°\ 20'$, and as c is $79°\ 56'$, angle C will be less than 90°, and B and C are of the same affection, therefore A will be more than 90°.

To find A :—

Sin comp c = tan B, tan comp A

cos c = tan B, cot A.

∴ cos c, cot B = cot A.

$c = 79°\ 56'$	cos 9·242526
$B = 83°\ 20'$	cot 9·067752
$88°\ 49'\ 48''$	cot 8·310278
$A = 91°\ 10'\ 12''$	1976
	1698

To find b :—

Sin comp b = cos B, cos comp c

cos b = cos B, sin c.

$c = 79°\ 56'$	sin 9·993262
$B = 83°\ 20'$	cos 9·064806
$b = 83°\ 26'\ 11''$	cos 9·058068
	271
	203

To find C :—

sin B = tan comp c, tan C.

sin B = cot c, tan C.

sin B, tan c = tan C.

$c = 79°\ 56'$	tan 10·750736
$B = 83°\ 20'$	sin 9·997053
$C = 79°\ 51'\ 58''$	tan 10·747789
	444
	345

$A = 91°\ 10'\ 12''$.

$C = 79°\ 51'\ 58''$

$b = 83°\ 26'\ 11''$.

It should be observed that in quadrantal triangles as in R.A. triangles the angles and sides opposite them are always of the same affection (omitting the side = 90°).

As a check on your working, it may be noted in quadrantal triangles that when any angle is acute its opposite side is larger than the angle, and when obtuse its opposite side is smaller.

The reverse is the case in R.A. triangles.

Worked Example 5.

In quadrantal triangle $A\,B\,C$, given $a = 90°$, $B = 81°\ 20'$, $C = 101°\ 40'$; to find A, b, and c.

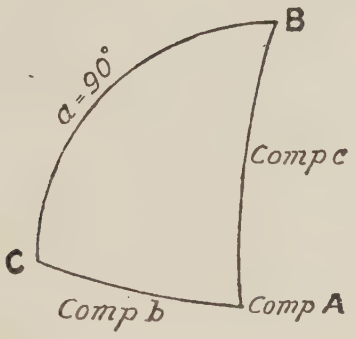


Fig. 35.

In this case the two adjacent angles to the quadrantal side a are of unlike affection as B is under 90° and C is over 90°, therefore A will be under 90°, and side b will be under 90°, and side c over 90°.

To find A :—

Sin comp A = cos B, cos C
cos A = cos B, cos C.

B =	81° 20′	cos 9·178072
C =	101° 40′	cos 9·305819
A =	88° 15′ 14″	cos 8·483891

To find b :—

Sin C = tan B, tan comp b.
Sin C, cot B = cot b.

B =	81° 20′	cot 9·183059
C =	101° 40′	sin 9·990934
b =	81° 30′ 35″	cot 9·173993

To find c :—

Sin B = tan C, tan comp c.
Sin B, cot C = cot c.

B =	81° 20′	sin 9·995013
C =	101° 40′	cot 9·314885
	78° 27′ 47″	cot 9·309898
c =	101° 32′ 13″	

A = 88° 15′ 14″.
b = 81° 30′ 35″.
c = 101° 32′ 13″.

Examples for Exercise B.

(1) In spherical triangle $A\,B\,C$, $A = 90°$, $A\,C = 70°$, $A\,B = 51°\ 58'\ 57''$; to find the other parts.

(2) In spherical triangle $X\,Y\,Z$, $X = 90°$, $Z = 77°\ 0'\ 23''$, $Y = 41°\ 43'\ 3''$; to find the remaining parts.

(3) $A = 90°$, $b = 115°\ 30'\ 1''$, $C = 124°\ 56'\ 8''$; find a, B, and c.

(4) $M = 90°$, $N = 118°\ 29'\ 23''$, $n = 128°$; solve the triangle.

(5) In spherical triangle $A\,B\,C$, $c = 90°$, $A = 101°\ 25'\ 2''$, $b = 84°\ 41'$; find the remaining parts.

(6) In a R. A. spherical triangle the hypotenuse $= 112°$, and one of its adjacent angles $= 45°\ 35'\ 20''$; find the other parts of the triangle.

(7) In a spherical triangle two arcs of 78° and 108° contain a right angle; find the other parts of the triangle.

(8) In spherical triangle $A\,B\,C$, $B = 90°$, $A = 47°\ 30'$, $a = 47°\ 30'$; find the other parts of the triangle without working it.

(9) In spherical triangle $A\,B\,C$, $B = 90°$, $A = 90°$, $a = 90°$. Can we find C and c?

(10) In spherical triangle $K\,L\,M$, $M = 90°$, $k = 66°\ 59'\ 59''$, $L = 78°\ 55'\ 45''$; find the other parts.

(11) In spherical triangle $A\,B\,C$, $a = 90°$, $b = 152°\ 26'\ 50''$, $C = 82°\ 10'$; find the remaining parts.

(12) $A = 90°$, $B = 57°\ 15'\ 58''$, $C = 68°\ 30'\ 2''$; find a, b, and c.

(13) $B = 90°$, $c = 28°\ 27'\ 30''$, $A = 106°\ 24'\ 1''$; find b, C, and a.

(14) $C = 90°$, $B = 77°\ 2'$, $b = 71°\ 1'$; solve the triangle.

(15) $B = 90°$, $a = 79°\ 40'\ 5''$, $C = 161°\ 47'\ 9''$; find b, A, and c.

(16) In spherical triangle $A\,B\,C$, $c = 90°$, $a = 110°\ 22'$, $B = 125°\ 30'$; find the remaining parts.

(17) $B = 90°$, $b = 54°\ 20'$, $A = 60°\ 20'\ 24''$; to find a, C, and c.

(18) $A = 90°$, $b = 22°\ 10'\ 25''$, $C = 66°\ 30'\ 22''$; to find a, B, and c.

(19) $B = 90°$, $a = 57°\ 15'\ 10''$, $b = 58°\ 32'\ 1''$; to find A, C, and c.

PROBLEMS IN RIGHT-ANGLED AND QUADRANTAL SPHERICAL TRIGONOMETRY.

WORKED EXAMPLE 1.

The latitude of an observer is 45° N. and the sun's declination is 23° S. Find the true amplitude of the sun and the time of sunrise.

The figure for this problem is constructed in the same manner as the figure for the **Amplitude** problem.

In Fig. 36 the circle represents the rational horizon, Z the observer's zenith, P the elevated pole, X the sun when rising, $N\,Z\,S$ the observer's meridian, $E\,Z\,W$ the prime vertical, $E\,Q\,W$ the equinoctial, $X\,D\,d$ the parallel of declination. It is required to find $E\,X$ or angle $E\,Z\,X$ = the true amplitude.

In spherical triangle $P\,N\,X$, $N\,P$ = elevated angle of celestial pole = latitude, $P\,X$ = polar distance of sun. As $Z\,N$ = radius of circle it is at right angles to circumference, therefore angle $P\,N\,X = 90°$.

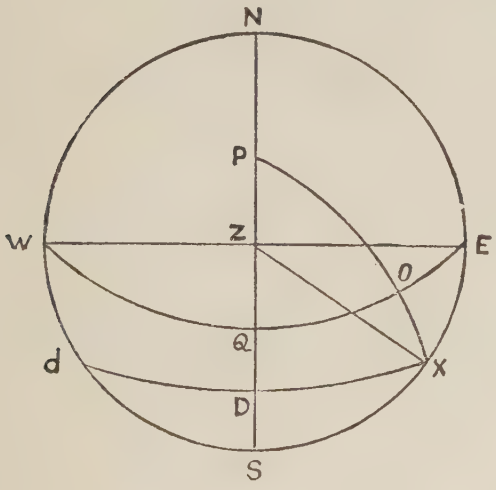


Fig. 36.

To find $N\,X$:—

Sin comp $P\,X$	= cos $N\,P$, cos $N\,X$
cos $P\,X$	= cos $N\,P$ cos $N\,X$
cos $P\,X$, sec $N\,P$	= cos $N\,X$.

Now, $P\,O = 90°$, $\therefore$ $O\,X$ is the complement of $P\,X$, and $O\,X$ = declination.

Also $N\,E = 90°$, and $E\,X$ is the complement of $N\,X$, and $E\,X$ = amplitude.

Substituting these complements, we get :—

	Sin $O\,X$, sec $N\,P$	= sin $E\,X$
i.e.,	sin dec. × sec lat.	= sin amp.
	$O\,X = 23°$	sin 9·591878
	$N\,P = 45°$	sec 10·150515
	$E\,X = 33°\ 32'\ 39''$	sin 9·742393

Sun's true amplitude = E. 33° 32′ 39″ S.

Angle $Z\,P\,X$ is the hour angle of the sun or time from noon, and $Z\,P\,X$ is the supplement of the angle $N\,P\,X$.

In spherical triangle $P\,N\,X$, angle $N = 90°$, $N\,P$ = lat. = 45°, $P\,X$ = polar dist. = 113° ; to find P.

Sin comp P = tan $N\,P$, tan comp $P\,X$.

cos P = tan $N\,P$ cot $P\,X$.

But the cosine of an angle = the cosine of its supplement.

i.e., cos $N\,P\,X$ = cos $Z\,P\,X$.

$\therefore$ cos $Z\,P\,X$ = tan $N\,P$ tan $O\,X$

cos $H\,A$ = tan lat. × tan dec.

$N\,P = 45°$	tan	10·000000
$O\,X = 23°$	tan	9·627852
4h. 19m. 32s.	cos	9·627852

	h.	m.	s.
Hour angle, . .	4	19	32
	12	0	0
Time of sunrise, .	07	40	28

Worked Example 2.

An observer in latitude 51° N. wishes to take an observation of a star when it is on the prime vertical to the Westward. Its declination is 35° N. Find its altitude and hour angle at that time.

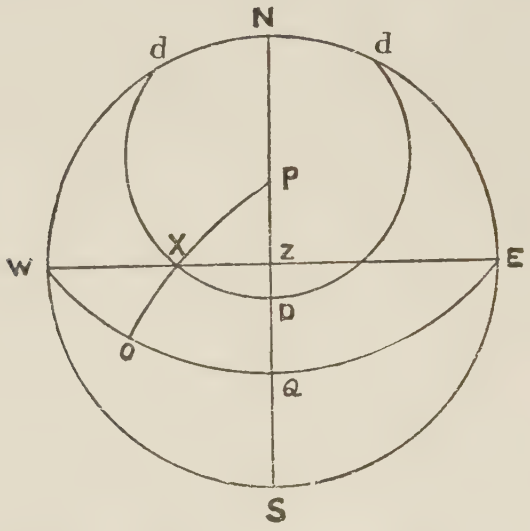


Fig. 37.

In the figure, the circle represents the rational horizon, etc., as in the last example.

In spherical triangle $P\,Z\,X$, given $Z = 90°$, $P\,Z = 39°$ (the co-lat.), $P\,X = 55°$ (the polar dist.) ; required to find $Z\,X$ (the co-altitude) and P (the hour angle).

To find $Z\,X$.—Sin comp $P\,X$ = cos $P\,Z$ cos $Z\,X$

or, cos $P\,X$ sec $P\,Z$ = cos $Z\,X$.

$P\,X = 55°$	cos 9·758591	Co-altitude, 42° 26′
$P\,Z = 39°$	sec 0·109497	90° 0′
$Z\,X = 42°\ 26'$	cos 9·868088	Altitude, 47° 34′

To find P.—Sin comp P = tan comp $P\,X$ tan $P\,Z$

or, cos P = cot $P\,X$ tan $P\,Z$.

$P\,X = 55°$	cot 9·845227	
$P\,Z = 39°$	tan 9·908369	
P = 3h. 41m. 50s.	cos 9·753596	Hour angle, 3h. 41m. 50s. W.

The construction of the figure is begun in the same way as for the "amplitude" and chronometer problems, but the position of the object is found somewhat differently.

The star **must** be on its circle of declination, and the question says "when it is on the prime vertical" to the Westward. It must, therefore, be at that point (to the west of the observer) where the circle of declination is intersected by the prime vertical, which is at X.

Worked Example 3.

The meridian altitudes of a circumpolar star are 15° North, and 65° South, of an observer. Find its altitude when on the prime vertical.

In figure, $N\,X$ = star's altitude north of observer, $S\,Y$ = star's altitude south of observer.

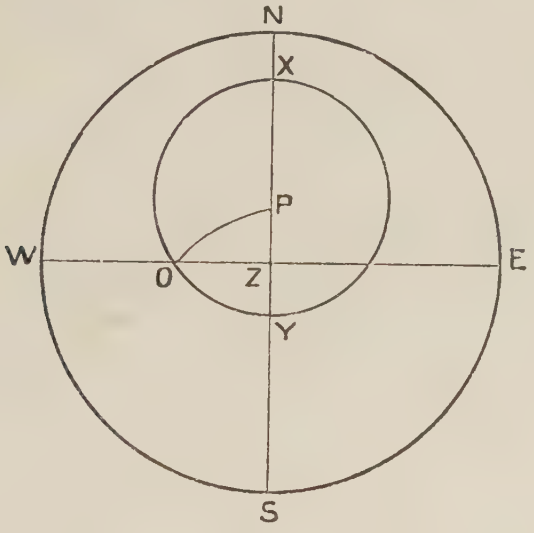


Fig. 39.

$$N\,X + P\,X = \text{latitude (1)}$$
$$N\,Y - P\,Y = \text{latitude (2)}$$
$$\therefore \quad \frac{N\,X + N\,Y}{2} = \text{latitude}$$
$$i.e., \quad \frac{15^\circ + 115^\circ}{2} = \text{latitude}$$

$\therefore$ Lat. = 65° N.

$P\,X$ = polar dist. = $P\,N - N\,X = 65^\circ - 15$.

$\therefore$ $P\,X = 50^\circ$.

In R.A. spherical triangle $P\,Z\,O$, $P\,O = P\,X = 50^\circ$, $P\,Z$ = co-latitude = 25°, to find $Z\,O$ = zenith distance when star is on prime vertical, and $O\,W$ = altitude.

$$\text{Cos } P\,O = \cos P\,Z \cos Z\,O,$$
$$\cos P\,O \sec P\,Z = \cos Z\,O$$
$$\cos P\,O \sec P\,Z = \sin O\,W.$$

$P\,O = 50^\circ\ 0'\ 0''$	cos =	9·808067
$P\,Z = 25\ \ 0\ \ 0$	sec =	10·042724
$OW = 45\ 10\ 22$	sin =	9·850791

$\therefore$ Altitude on prime vertical = 45° 10′ 22″.

Examples for Exercise C.

(1) In latitude 44° 0′ N., sun's declination 22° S., find the true amplitude and the time of sunset.

(2) In latitude 0°, the sun when rising bore N. 81° E., find the sun's declination without calculation.

(3) In latitude 40° 30′ S., sun's declination 15° 27′ S., find the apparent time the sun will be on the prime vertical in the morning.

(4) In latitude 23° N., sun's declination 23° N., find the time in hours, minutes, and seconds the sun will be below the horizon.

(5) A star whose R.A. was 17h. 21m. 10s. and declination 28° 36′ S. was on the prime vertical **east** of observer in latitude 51° 36′ S., and at the same time another star of declination 10° S. was on the prime vertical **west** of observer, find the R.A. of the latter.

(6) The angular distance between a star and a light on the horizon was 66° 24′, the difference in their bearings was 44° 30′, find the altitude of the star.

(7) In latitude 50° 48′ N. an observer takes the altitudes of two stars, both bearing East, one 20° and the other 40°, find the difference in their right ascensions.

(8) The sun's altitude at 6h. 0m. P.M. was 18° 45′ and its declination 20° 4′ N., find the latitude.

(9) At 9h. 0m. A.M. the sun's altitude was 22° 56′ and its declination 0°, find the latitude.

(10) The altitude of a star was 47° 30′, and at the same time its angular measurement from a light on the horizon to the right of it was 99° 30′. The star's azimuth was N. 16° W., find the true bearing of the light.

QUADRATIC EQUATIONS

An equation means that two quantities are equal.

Thus $8+4=5+7$ because by collecting the terms on each side of the equation we have $12=12$.

Now instead of using numbers we may use symbols.

Thus $8+6=x$, or $14=x$. Also $9+6-2=x$, or $13=x$.

These are examples of exceedingly easy simple equations (x which is called the unknown quantity being obvious), and are usually called identities.

"Factors" are numbers which being multiplied together equal the product, thus in the simple equation $5\times4=20$, 5 and 4 are factors of 20.

If we have $5x=20$, then 5 and x are the factors. To find the value of the unknown quantity x, we must devise a means whereby we can do away with the factor 5. It is easily seen that by dividing both sides of the equation by 5 we obtain $x=4$.

When one of the factors of an expression is a numerical quantity it is called a *co-efficient* of the remaining factor. Thus in the above $5x$, 5 is the co-efficient; and in the equation $3x^2+4x=18$, 3 is the co-efficient in $3x^2$, and 4 is the co-efficient in $4x$.

This also applies when a fraction of the unknown quantity has to be considered, such as $\frac{x}{4}$. $\frac{x}{4}$ really means $\frac{1}{4}\,x$ so that in this case $\frac{1}{4}$ is the co-efficient.

A quadratic equation is an equation which contains the square of the unknown quantity.

Should a quadratic equation contain the square of the unknown quantity *only*, it is called **a pure quadratic.**

For example, if $4x^2=36$, find the value of x.

$x^2=9$.....divide both sides by 4.

$x=3$.....by taking the square root of each side.

Also if $5x^2=125$, find the value of x.

$x^2=25$.....divide both sides by 5.

$x=5$.....by taking the square root of each side.

Should the equation contain the square **and the first power** of the unknown quantity, it is called **an adfected quadratic.**

The easiest way to solve an adfected quadratic equation is to add the square of half the co-efficient of the unknown quantity to each side of the equation to make each side a perfect square.

EXAMPLE A.

Find a value of x in the following equation:—$x^2+4x=32$.

$x^2+4x=32$

$x^2+4x+(2)^2=32+(2)^2$ .....by adding the square of half the co-efficient of x to each side.

$=36$

$x+2 = \pm\sqrt{36}$.....by taking the square root of each side.*

$= \pm 6$

$x = \pm 6-2$.....by transposing.

If we consider $+6-2$, then the value of $x=4$.

If we consider $-6-2$, then the value of $x=-8$.

Both answers satisfy the equation, but as the questions given usually only require a value of the unknown quantity, we do not, as a rule, work out any but the positive value.

We should, however, always prefix both plus and minus signs to the $\sqrt{\ }$, as a plus multiplied by a plus, or a minus multiplied by a minus, both give a positive result.

---

* The square root of the left hand side of the equation is obtained by taking x (the square root of x^2), and the square root of the square of half the co-efficient, which is 2.

$(x+2)^2=(x+2)$ multiplied by $(x+2)=x^2+4x+(2)^2$.

$x+2$

$x+2$

---

x^2+2x

$+2x+4$

$x^2+4x+4=x^2+4x+(2)^2$.

Example B.

Find a value of x in the following equation:—$2x^2+4x=48$.

This is an example of an adfected quadratic containing a factor (or co-efficient) of the square of the unknown quantity.

The best way to solve it is to divide throughout the equation by the co-efficient (or factor) of the square of the unknown quantity (which in this case is 2) to reduce the square term co-efficient to 1.

$2x^2+4x=48$

$x^2+2x=24$ ..... divide throughout by 2.

$x^2+2x+(1)^2=24+(1)^2$....by adding the square of half the co-efficient of the unknown quantity to each side.

Half of the co-efficient 2 being 1.

$=25$

$x+1 = \pm\sqrt{25}$.....by taking the square root of each side.*

$= \pm 5$

$x = \pm 5, -1$ .....by transposing.

If we consider $+5-1$, then the value of $x=4$.

If we consider $-5-1$, then the value of $x=-6$.

---

* The square root of the left hand side of the equation is obtained by taking x (the square root of x^2), and the square root of the square of half the co-efficient, which is 1.

$(x+1)$ multiplied by $(x+1)=x^2+2x+(1)^2$

EXAMPLE C.

Find the value of x when $x^2+4x=117$.

$x^2+4x=117$

$x^2+4x+(2)^2 = 117+(2)^2$ .....by adding the square of half the co-efficient of x to each side.

$= 121$

$x+2 = \pm\sqrt{121}$ .....by taking the square root of each side.*

$= \pm 11$

$x = \pm 11-2$ .....by transposing.

We still have the equation only partly solved because $x = +11$ or -11, as $+11 \times +11 = 121$, and $-11 \times -11 = 121$.

A minus multiplied by a minus equals a positive amount. We have therefore to use both signs to get the correct values.

If we take $+11-2$, then $x = 9$.
If we take $-11-2$, then $x = -13$.

---

* The square root of any quantity that has been made a perfect square (as the above) may be found by taking the first symbol and the square root of the last term, *i.e.* $x+2$ (see also note to example *A*).

EXAMPLE D.

Find the value of x when $x^2-4x=45$.

$x^2-4x=45$

$x^2-4x+(2)^2=45+(2)^2$ .....by adding the square of half the co-efficient of x to each side.

$= 49$

$x-2 = \pm\sqrt{49}$ .....by taking the square root of each side.*

$= \pm 7$

$x = \pm 7+2$ .....by transposing.

If we take $+7+2$, then $x=9$.
If we take $-7+2$, then $x=-5$.

---

* It will be noticed that we have put $x-2$ as the square root of the left hand value although it contains $+(2)^2$. We could not put $x+2$ as the square root, because $(x+2)^2=x^2+4x+(2)^2$ as previously stated.

The fact that $x-2$ is correct is proved by the following working:—

$$\begin{array}{l} x-2 \\ x-2 \\ \hline x^2-2x \\ \quad -2x+4 \\ \hline \underline{x^2-4x+4} \text{ or } \underline{x^2-4x+(2)^2} \end{array}$$

Thus should a minus sign precede the simple term, the square root must contain the minus sign.

We will now consider the same kind of equations in trigonometry instead of algebra, first taking some pure quadratics and going on with adfected quadratics afterwards.

Before doing so it will be an immense advantage to make sure that you clearly remember some of the fundamental formulae and the reciprocals, so as to be able to quickly change unlike terms into terms of the same name. They are as follows:—

$$\begin{aligned} & \operatorname{Sin}^2 A + \operatorname{Cos}^2 A = 1 \\ \therefore\ & \operatorname{Sin}^2 A = 1 - \operatorname{Cos}^2 A \\ \text{and}\ & \operatorname{Cos}^2 A = 1 - \operatorname{Sin}^2 A \end{aligned} \Big\} \text{ by transposing.}$$

$$\begin{aligned} & \operatorname{Sec}^2 A = 1 + \operatorname{Tan}^2 A. \\ \therefore\ & \operatorname{Sec}^2 A - 1 = \operatorname{Tan}^2 A \\ \text{and}\ & \operatorname{Sec}^2 A - \operatorname{Tan}^2 A = 1 \end{aligned} \Big\} \text{ by transposing.}$$

$$\begin{aligned} & \operatorname{Cocec}^2 A = 1 + \operatorname{Cot}^2 A \\ \therefore\ & \operatorname{Cosec} A - 1 = \operatorname{Cot}^2 A \\ \text{and}\ & \operatorname{Cosec}^2 A - \operatorname{Cot}^2 A = 1 \end{aligned} \Big\} \text{ by transposing.}$$

$$\operatorname{Cosec} A = \frac{1}{\sin A} \qquad \operatorname{Sin} A = \frac{1}{\operatorname{cosec} A}$$

$$\operatorname{Cos.} A = \frac{1}{\sec A} \qquad \operatorname{Sec} A = \frac{1}{\cos A}$$

$$\operatorname{Tan} A = \frac{1}{\cot A} \qquad \operatorname{Cot} A = \frac{1}{\tan A}$$

$$\operatorname{Tan} A = \frac{\sin A}{\cos A} \qquad \operatorname{Cot} A = \frac{\cos A}{\sin A}$$

These may be considerably added to, but are enough for present requirements.

EXAMPLE E.

If $\sin^2 A+1=1\frac{1}{2}$, find a value of A.

$\sin^2 A+1=1\frac{1}{2}$

$\sin^2 A = \frac{1}{2}$

$\sin A = \pm \frac{1}{\sqrt{2}}$ .....by taking the square root of each side.

We have not *worked out* the value of A, it being assumed that the student is familiar with the fact that $\frac{1}{\sqrt{2}}$ is the sine of 45°

A value of A is therefore 45°.

EXAMPLE F.

If $\sec^2 A+1=5$, find a value of A.

$\sec^2 A+1=5$

$\sec^2 A=4$

$\sec A = \pm 2$ .....by taking the square root of each side.

2 is the secant of 60°.

A value of A is therefore 60°.

EXAMPLE G.

Find a value of A when $\cos^2 A+\frac{1}{4}=1$.

$\cos^2 A+\frac{1}{4}=1$

$\cos^2 A=\frac{3}{4}$

$\cos A = \pm\sqrt{\frac{3}{4}} = \pm\frac{\sqrt{3}}{2}$ which is the cos of 30°.

A value of A is therefore 30°.

EXAMPLE H.

Find a value of A if $\operatorname{cosec}^2 A+\cos^2 A+\sin^2 A=5$.

$\operatorname{cosec}^2 A+\cos^2 A+\sin^2 A=5$

$\operatorname{cosec}^2 A+1 = 5$.....substitute 1 for $\cos^2 A+\sin^2 A$.

$\operatorname{cosec}^2 A = 4$

$\operatorname{cosec} A = \pm\sqrt{4}$.....by taking the square root of each side.

$\operatorname{cosec} A = \pm 2$ which is the cosec of 30°.

A value of A is therefore 30°.

Example J.

If $\cot^2 A+\frac{1}{\sin^2 A}=3$, find a value of A.

$\cot^2 A+\frac{1}{\sin^2 A}=3$

$\cot^2 A+\operatorname{cosec}^2 A=3$ .....substitute $\operatorname{cosec}^2 A$ for $\frac{1}{\sin^2 A}$

$\cot^2 A+1+\cot^2 A=3$ .....substitute $1+\cot^2 A$ for $\operatorname{cosec}^2 A$

$2\cot^2 A=2$

$\cot^2 A=1$

$\cot A=\pm 1$ .....by taking the square root of each side.

1 is the cot of 45° **A value of A is therefore 45°**

Example K.

Find a value of A when $6\cos^2 A-\cos A=1$

$6\cos^2 A-\cos A=1$

$\cos^2 A-\frac{1}{6}\cos A=\frac{1}{6}$ .....divide each side by 6.

$\cos^2 A-\frac{1}{6}\cos A+(\frac{1}{12})^2=\frac{1}{6}+(\frac{1}{12})^2$ .....add the square of half the co-efficient of A to each side.

$$=\frac{1}{6}+\frac{1}{144}=\frac{144+6}{864}=\frac{150}{864}=\frac{25}{144}$$

$\cos A-\frac{1}{12}=\pm\sqrt{\frac{25}{144}}=\pm\frac{5}{12}$ ....take the square root of each side.

$\cos A=\pm\frac{5}{12}+\frac{1}{12}=\frac{6}{12}=\frac{1}{2}$ .....transpose

$\frac{1}{2}$ is the cos of 60° **A value of A is therefore 60°**

Example L.

Find a value of A if $4\cos A-3\sec A=0$

$4\cos A-3\sec A=0$

$4\cos A-\frac{3}{\cos A}=0$

$4\cos^2 A-3=0$

$4\cos^2 A=3$ .....transpose.

$\cos^2 A=\frac{3}{4}$ .....divide each side by 4.

$\cos A=\pm\sqrt{\frac{3}{4}}=\frac{\sqrt{3}}{2}$ .....take the square root of each side.

$\frac{\sqrt{3}}{2}$ is the cos of 30° **A value of A is therefore 30°**

EXAMPLE M.

If $2 \sin^2 A - 3 \cos A = 0$, find a value of A.

$2 \sin^2 A - 3 \cos A = 0$

$2(1-\cos^2 A) - 3 \cos A = 0$ ..... substitute $(1-\cos^2 A)$ for $\sin^2 A$

$2 - 2\cos^2 A - 3 \cos A = 0$ ..... multiply.

$-2\cos^2 A - 3 \cos A = -2$ ..... transpose.

$2\cos^2 A + 3 \cos A = 2$ ..... change signs on both sides of equation.

$\cos^2 A + \frac{3}{2} \cos A = 1$ ..... divide each side by 2.

$\cos^2 A + \frac{3}{2} \cos A + (\frac{3}{4})^2 = 1 + (\frac{3}{4})^2 = 1 + \frac{9}{16} = \frac{25}{16}$ ..... add the square of half the co-efficient to each side.

$\cos A + \frac{3}{4} = \pm \sqrt{\frac{25}{16}} = \pm \frac{5}{4}$ ..... take the square root of each side.

$\cos A = \pm\frac{5}{4} - \frac{3}{4} = \frac{1}{2}$

$\frac{1}{2}$ is the cos of 60° **A value of A is therefore 60°.**

Here follow a few more difficult equations in which it is necessary to use logarithms.

Example N.

Find a value of A in the following equation:—$\sin^2 A + \frac{3}{\text{cosec } A} = \cdot 76$.

$\sin^2 A + \frac{3}{\text{cosec } A} = \cdot 76$

$\sin^2 A + 3 \sin A = \cdot 76$ .....substitute 3 sin A for $\frac{3}{\text{cosec } A}$

$\sin^2 A + 3 \sin A + (1\cdot 5)^2 = \cdot 76 + (1\cdot 5)^2 = \cdot 76 + 2\cdot 25$....add the square of half the co-efficient to each side.

$= 3\cdot 01$

$\sin A + 1\cdot 5 = \pm \sqrt{3\cdot 01}$ .....take the square root of each side.

$\sin A = \pm \sqrt{3\cdot 01} - 1\cdot 5$ .....transpose

Work out the value of the right hand side by logs.

3·01	log	0·478566.....divide by two
$\sqrt{3\cdot 01}$	log	0·239283
next less	log	239049 = 1·734
	diff.	250)2340(936
		2250
		900
		750
		1500
		1500

$\sqrt{3\cdot 01} = 1\cdot 734936$

Carry on with the equation:—

$$\sin A = 1\cdot 734936 - 1\cdot 5$$
$$\therefore \sin A = 0\cdot 234936$$

This is the *natural* sine, and can be taken direct from *Norie's Tables.*

Natural sine A is 0·234936
next less is 0·234859 giving 13° 35′
Difference between given and next less is 77

Difference between next less and next greater is 283
The number of seconds to be added to 13° 35′ is found by proportion:—

$$283 : 77 :: 60 : x$$

77
60
283)4620(16
283
1790
1698

A value of A is 13° 35′ 16″

The value of A may also be found by using the *log* sine, as follows:—
The *natural* sine of A is 0·234936

Take out the common log of this number (adding 10 to the index)	0·2349	log	9·370883.....diff.	185
		+	67	36
	log sine		9·370950	1110
				555
				66,60

Gives the value of A as 13° 35′ 16″

Example O.

If $\cos A \operatorname{cosec} A + \operatorname{cosec}^2 A = 11$, find a value for A

$\cos A \operatorname{cosec} A + \operatorname{cosec}^2 A = 11$

$\cos A \frac{1}{\sin A} + \operatorname{cosec}^2 A = 11$ ..... substitute.

$\frac{\cos A}{\sin A} + \operatorname{cosec}^2 A = 11$ ..... substitute.

$\cot A + \operatorname{cosec}^2 A = 11$ ..... substitute.

$\cot A + 1 + \cot^2 A = 11$ ..... substitute.

$\cot^2 A + \cot A + 1 = 11$ ..... re-arrange.

$\cot^2 A + \cot A = 10$ ..... transpose.

$\cot^2 A + \cot A + (\frac{1}{2})^2 = 10 + (\frac{1}{2})^2 = 10{\cdot}25$ ..... add the square of half the coefficient to each side.

$\cot A + \frac{1}{2} = \pm \sqrt{10{\cdot}25}$ ..... take the square root of each side.

$\cot A = \pm \sqrt{10{\cdot}25} - {\cdot}5$ transpose.

Work out the value of the right hand side by logs.

10·25 log 1·010724 ..... divide by two

$\sqrt{10{\cdot}25}$ log 0·505362

next less log 505286 = 3·201

diff. 136)760(558

680

806

680

1200

1088

112

$\sqrt{10{\cdot}25} = 3{\cdot}201559$

Carry on with the equation

$$\cot A = 3{\cdot}201559 - {\cdot}5$$
$$\therefore \cot A = 2{\cdot}701559$$

This is the *natural* cotangent, which can be taken direct from *Norie's Tables.*

A value of A is 20° 18′ 45″

The value of A may also be found by using the *log* cotangent, as follows:—

The *natural* cotangent of A is 2·701559

diff. 160

559

1440

800

800

89,440

Take out the common log of this number (adding 10 to the index) 2·701 log 10·431525

\+ 89

log cotan 10·431614

Gives the value of A as 20° 18′ 45″

Example P.

Find a value for A in the following equation:—$2\cos A - \sin^2 A = \cdot 83$.

$2\cos A - \sin^2 A = \cdot 83$

$2\cos A - (1 - \cos^2 A) = \cdot 83$ .....substitute

$2\cos A - 1 + \cos^2 A = \cdot 83$ .....remove brackets.

$2\cos A + \cos^2 A = 1 \cdot 83$ .....transpose

$\cos^2 A + 2\cos A = 1 \cdot 83$ .....re-arrange

$\cos^2 A + 2\cos A + (1)^2 = 1 \cdot 83 + (1)^2 = 2 \cdot 83$ add the square of half the co-efficient to each side.

$\cos A + 1 = \pm\sqrt{2 \cdot 83}$ .....take the square root of each side.

$\cos A = \pm\sqrt{2 \cdot 83} - 1$ .....transpose

Work out the value of the right hand side by logs.

$2 \cdot 83$ log $0 \cdot 451786$ .....divide by two

$\sqrt{2 \cdot 83}$ log $0 \cdot 225893$

next less log $225826 = 1 \cdot 682$

diff. 258)670(259

516

1540

1290

2500

2322

178

$\sqrt{2 \cdot 83} = 1 \cdot 682260$

Carry on with the equation

$$\cos A = 1 \cdot 682260 - 1$$

$$\therefore \cos A = 0 \cdot 682260$$

This is the *natural* cosine which can be taken direct from Norie's tables

A value of A is $46^\circ\ 58'\ 46''$

The value of A may also be found by using the *log* cosine, as follows:—

The *natural* cosine of A is $0 \cdot 682260$

Tale out the common log of this number (adding 10 to the index).	0 6822	log $9 \cdot 833912$	.....diff	64
		+ 38		60
	lcg cosine	$9 \cdot 833950$		38,40

Gives the value of A as $46^\circ\ 58'\ 46''$

OBLIQUE SPHERICAL TRIGONOMETRY.

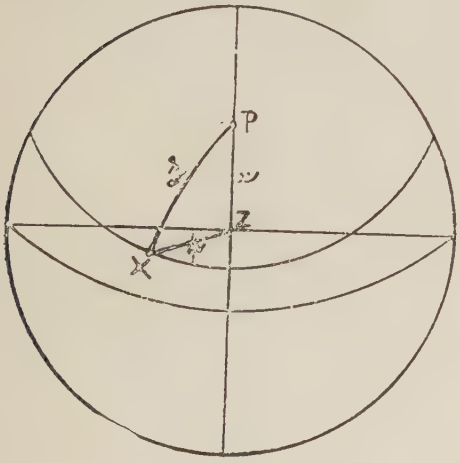
The Haversine Formula.

The solving of oblique spherical triangles by what is known as **the haversine formula** is becoming increasingly popular, both in ordinary practice at sea and for use in many of the problems set at the examinations.

Its principal advantage is that the fundamental formula once being written down, the formula for finding the other required parts of the triangle may easily be deduced from it; it is therefore only necessary that *one* formula should be learnt.

It should be absolutely committed to memory, and may be stated as follows:—

The haversine of an angle equals the haversine of its opposite side minus the haversine of the difference between its two adjacent sides, divided by the product of the sines of its two adjacent sides.



This would be written down as shown below:

In triangle $P\ Z\ X$

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (P\,Z \sim P\,X)}{\sin P\,Z \ \sin P\,X}$$

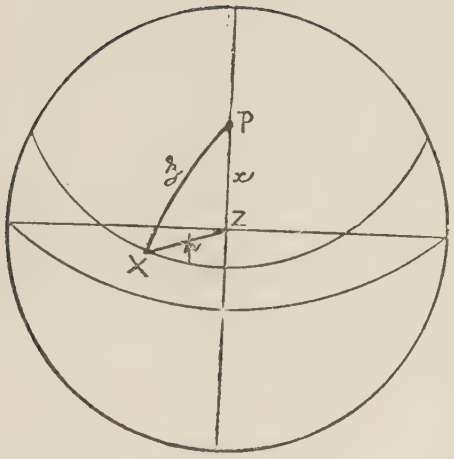
$$\text{Hav. } Z = \frac{\text{hav. } z - \text{hav. } (Z\,P \sim Z\,X)}{\sin Z\,P \ \sin Z\,X}$$

$$\text{Hav. } X = \frac{\text{hav. } x - \text{hav. } (X\,Z \sim X\,P)}{\sin X\,Z \ \sin X\ P}$$

Examples of the working of this formula are given on the next and following pages. It has been used for finding the hour angle, altitude azimuth, meridian zenith distance in "reduction to the meridian," and the courses and distance in "great circle sailing" in all the problems in this book.

The Haversine Formula.

To find P (the hour angle).



$PZ = 50°$
$PX = 70°$
$ZX = 40° = p$

Used in "Chronometer and azimuth" also in Longitude by star or planet, and Double altitude by Sumner's method.

In triangle PZX

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (PZ \sim PX)}{\sin PZ \sin PX}$$

This formula is worked out by copying down the natural haversine p, and subtracting from it the natural haversine of the difference between PZ and PX. The remainder is a natural haversine which is changed into a log haversine (found abreast of the natural haversine in the table of HAVERSINES).

The reason for changing the natural haversine into the log haversine is this: To complete the working we have to divide hav. p — hav $(PZ \sim PX)$ by sin PZ sin PX (that is, multiply it by cosec PZ cosec PX).

Numbers are multiplied together by means of adding their corresponding logs together. Adding *naturals* is only **adding** not multiplying. It is necessary that all the figures which we subtract from one another or add to each other should be of the same nature. We must not add a *log* cosecant to a *natural* haversine. Having subtracted the natural haversine $(PZ \sim PX)$ from the natural haversine p, the remainder is a natural haversine. For this natural haversine we therefore substitute its *log* haversine.

To this log hav. we then add the log cosec PZ and the log cosec PX. The three numbers which we finally add together are consequently all "logs", their sum being the log hav. P.

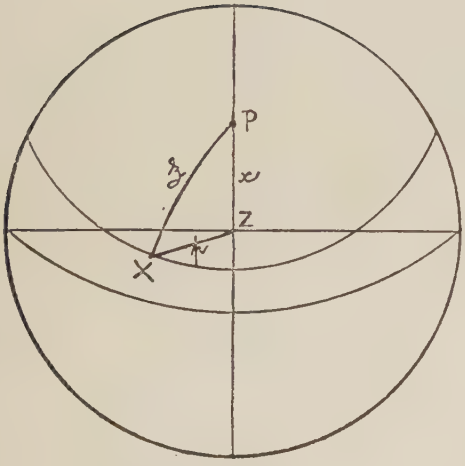
There are other ways of getting the value of P, but this is the best method and is the one usually adopted.

Working of the above formula:—

p	$= 40°$ nat. hav.	0·11698	
$(PZ \sim PX)$	$= 20°$ nat. hav.	0·03015	
	nat. hav.	0·08683	
	log hav.	8·93866	
PZ	$= 50°$ log cosec	0·11575	
PX	$= 70°$ log cosec	0·02701	
	log hav.	9·08142	..... $P = 2\ 42\ 35$ (h. m. s.)

EXAMPLES.

To find Z (the true azimuth).



Used in "Chronometer and azimuth"

$$\text{Hav. } Z = \frac{\text{hav. } z - \text{hav. } (Z\,P \sim Z\,X)}{\sin Z\,P \sin Z\,X}$$

The working is done in exactly the same way as when finding P in the preceding example.

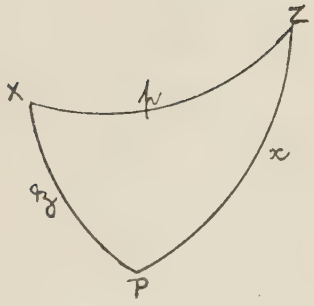
$Z\,P = 50°$
$P\,X = 70° = z$
$Z\,X = 40°$

z	$= 70°$	nat. hav.	0·32899
$(Z\,P \sim Z\,X)$	$= 10°$	nat. hav.	0·00760
		nat. hav.	0·32139
		log hav.	9·50704
$Z\,P$	$= 50°$	log cosec	0·11575
$Z\,X$	$= 40°$	log cosec	0·19193
		log hav.	9·81472

$Z = 107°\ 47'$ True azimuth N. 107° 47′ W.

The Haversine Formula.

To find angle X.



This formula has been used to find the courses in "Great Circle Sailing."

$$\text{Hav. } X = \frac{\text{hav. } x - \text{hav. } (XZ \sim XP)}{\sin XZ \ \sin XP}$$

$XZ = 96°\ 4{\cdot}4'$
$ZP = 77\ 56{\cdot}0 = x$
$XP = 44\ 13{\cdot}0$

The working is done in exactly the same way as when finding P and Z in the two preceding examples.

XZ	$= 96°\ 4{\cdot}4'$		
XP	$= 44\ 13{\cdot}0$		
$XZ \sim XP$	$= 51\ 51{\cdot}4$		
		$x = 77°\ 56'$ nat. hav.	0·39548
		$XZ \sim XP = 51\ 51{\cdot}4$ nat. hav	0·19119
		nat. hav.	0·20429
		log hav.	9·31024
XZ	$= 96°\ 4{\cdot}4'$	log cosec.	0·00244
XP	$= 44\ 13$	log cosec	0·15653
		log hav.	9·46921

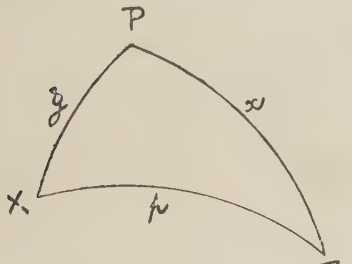
$X = 65°\ 44{\cdot}6'$

Initial course S. 65° 44·6′ E.

EXAMPLE.

To find side p (used in Great Circle Sailing and Marcq St. Hilaire).

Assuming p to represent the arc of a great circle between X and Z, its value is the distance between the two places.



$PX = 40°$
$PZ = 60°$
$P = 80°$

After writing down the fundamental formula, it is twice transposed to bring p by itself on one side of the equation.

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (PZ \sim PX)}{\text{sin. } PZ \text{ sin } PX}$$

transpose.... $(\text{Hav. } P \sin PZ \sin PX) = \text{hav. } p - \text{hav. } (PZ \sim PX)$

transpose.... $(\text{Hav. } P \sin PZ \sin PX) + \text{hav. } (PZ \sim PX) = \text{hav. } p$

The working out of this formula is done as follows:—

Write down the log hav. P, the log sin PZ, also the log sin PX, and find the sum of these logs which is the log haversine of the three values multiplied together.

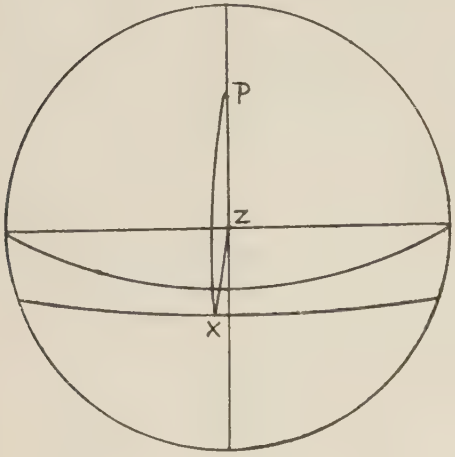
For this log haversine we now substitute its *natural* haversine so that we may add to it the *natural* haversine $(PZ \sim PX)$

Having done this, we obtain the natural haversine of p (the distance).

P	$= 80°$	log. hav.	9·61614
PZ	$= 60$	log sin.	9·93753
PX	$= 40$	log sin	9·80807
		log hav.	9·36174
		nat. hav.	0·23000
$(PZ \sim PX)$	$= 20°$	nat. hav.	0·03015
		nat. hav	0·26015 ..... p = 61° 20·1′
			60
		Distance	3680·1 miles.

The Haversine Formula.

To find $P\,Z \sim P\,X$ (the meridian zenith distance in "Reduction to the meridian.")



	m.	s.	
P	= 25°	27′	
$P\,Z$	= 61	46	approx.)
$P\,X$	=107	53·6	
$Z\,X$	= 46	29·6 = p	

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (P\,Z \sim P\,X)}{\sin P\,Z \ \sin P\,X}$$

transpose ..... (Hav. P sin $P\,Z$ sin $P\,X$) = hav. p − hav. $(P\,Z \sim P\,X)$

transpose ..... (Hav. P sin $P\,Z$ sin $P\,X$) − hav. p = − hav. $(P\,Z \sim P\,X)$

change + and − signs throughout the equation. } − (Hav. P sin $P\,Z$ sin $P\,X$) + hav. p = hav. $(P\,Z \sim P\,X)$

re-arrange ..... Hav. p − (hav. P sin $P\,Z$ sin $P\,X$) = hav. $(P\,Z \sim P\,X)$

The working out of this formula is done as follows:—

Write down the log hav. P, the log sin $P\,Z$, also the log sin $P\,X$, and find the sum of these logs which is the log hav. of the three values multiplied together.

For this log. hav. we now substitute its *natural* haversine, so that we may subtract it from the nat. hav. p.

Having done so, the remainder is the nat. hav. $(P\,Z \sim P\,X)$ which is the meridian zenith distance. The result may not be *strictly* accurate, but is quite good enough for all practical purposes and for use at the examinations.

	m.	s.		
P =	25	27	log hav.	7·48850
$P\,Z$ =	61°	46′	log sin	9·94499
$P\,X$ =	107	53·6	log sin	9·97847
			log hav.	7·41196
			nat hav.	0·00258
p =	46°	29·6′	nat hav.	0·15578
			nat. hav.	0·15320 ..... $P\,Z \sim P\,X$ = 46° 5.1′

STAR PROBLEMS.

In all the star problems, their declinations, etc., must be taken from page 1 of the month in the Nautical Almanac. The principal stars are arranged in this table in the order of their Right Ascension.

The R.A. and Declination of the stars are given for the middle of each month, and these elements are to be used throughout the month, without interpolation or correction.

LATITUDE BY MERIDIAN ALTITUDE OF A STAR.

This differs from the meridian altitude of the sun, only in the following :—

The star's declination needs no correction, therefore **the Greenwich Time is not wanted.**

In correcting the altitude, **no parallax or semi-diameter must be applied.**

The working is as follows :—

Write down the observed altitude, and to it apply the following corrections :—

Index error of sextant (if any).

Dip.

Refraction.

The result is the **true altitude.** Subtract the true altitude from 90° to get the **zenith distance.** Name the zenith distance **opposite** to the bearing of the star.

Open the *Nautical Almanac* at page 1 of the month, and take out the star's declination.

Place the declination with its proper name under the zenith distance, and proceed as in meridian altitude of the sun—that is, if they have **the same names add them together**, but if **different names subtract one from the other.**

The result is the latitude which must be named the **same name as the greater** one of the two.

Worked Example I.

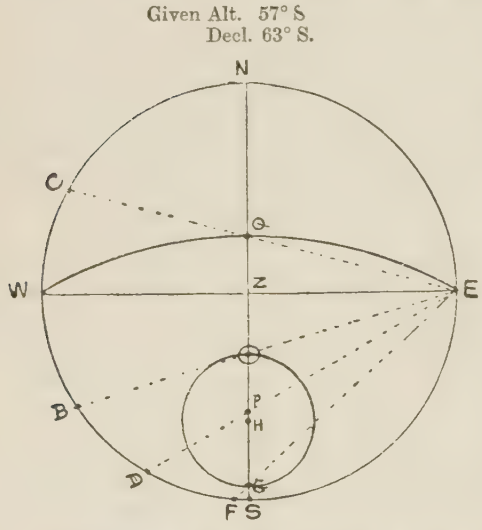
On 4th January, 1929, the observed meridian altitude of the star "a Crucis" was 57° 25′ bearing south of observer; index error 3′ 20″ to add, height of eye 18 feet. Required the Latitude.

The figure is constructed in exactly the same way as for meridian altitude of the sun.

Note that when the polar distance of an object is less than the observer's latitude that object never sets. It is above the horizon throughout the whole day and night, and is called "circumpolar."

This example has been specially chosen on that account, the dotted lines being put in to make the explanation clear. Draw them in pencil at the examination, and rub them out when the figure is finished, also marks *C B D F G* and *H*.

FIGURE FOR WORKED EXAMPLE I.



The altitude being 57° S. lay off 57° from S, making the mark *B*.

Draw a line from *B* to *E* which will cut the meridian in the position of the object on the meridian above the pole at the time of observation. Call it ⊙. The declination being 63° S., make the equinoctial mark (*C*) 63° North of *B*, this will be 60° from *N*. A line from *C* to *E* will cut the meridian at *Q*. Draw *W Q E*, which represents the equinoctial.

Take a chord of 90° in the compasses, and with one leg on *C* (the equinoctial mark) describe *D* (the pole mark) a line from *D* to *E* will cut the meridian in the position of the elevated pole (*P*).

Take the **polar distance** (*D B*) in the compasses, and with one leg on *D* describe the mark *F*. A line from *F* to *E* will cut the meridian in the position of the parallel (or circle) of declination below the pole. Call it *G*.

Bisect *G* ⊙ in *H*.

H ⊙ is radius of declination parallel.

Note that **if the polar distance is the same value as the latitude**, the parallel of declination will cut the meridian exactly on the horizon at *S*.

EXPLANATION OF THE FIGURE.

(To be written at the examination.)

The large circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial.
P the elevated pole.

The small circle represents the parallel of declination, the object being circumpolar—that is, above the horizon throughout the whole of the day and night.

⊙ is the object on the meridian above the pole at the time of observation.

From the figure it is seen that :—

Q ⊙ − *Z* ⊙ = *Z Q*, or Declination − zenith distance = latitude,

Observed Altitude,	57° 25′ S.		
Ind. Error,	+ 3·3		
	57 28·3		
Dip,	— 4·2		
	57 24·1		
Refraction,	— 0·6		
True Alt.,	57 23·5		
	90 0		
Zen. Dist.,	32 36·5 N.	}	Same names add.
Decl.,	62 42·0 S.	}	Diff. names subt.
Latitude,	30 5·5 S.		

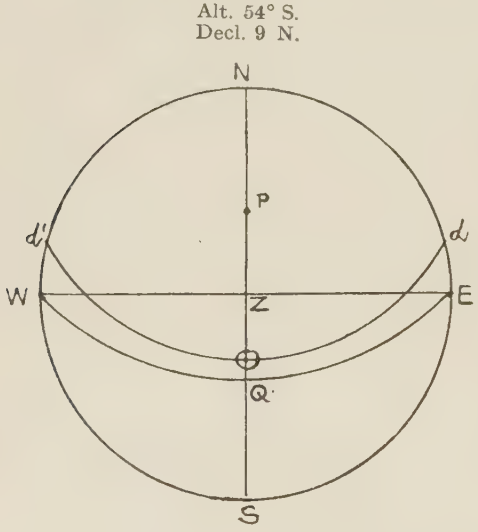
Worked Example II.

On 15th April, 1929, in latitude by account 44° 14′ N., longitude 158° E., compute the approximate observed meridian altitude of the star *α Aquilæ* (Altair) as a guide for setting the sextant, the height of eye being 20 feet, and index error 2′ to subtract.

FIGURE FOR WORKED EXAMPLE II.

The altitude being 54° S. of observer (it is found on the opposite page), lay off 54° from S., make a mark on the horizon and call it *B*.

All the lines and marks mentioned in the instructions, but not shown in the fig., should be drawn in pencil, and rubbed out when the figure is completed.



Draw a line across the figure from *B* to *E*, this line will cut the meridian at ⊙, which is the position of the object at the time of observation.

As the declination is 9° N., make a mark on the horizon 9° to the **Southward** of *B*, which will be 45° from S. Call this mark *C*. A straight line from *C* to *E* will cut the meridian in the position of the equinoctial. Put the equinoctial in (*W Q E*).

Take a chord of 90° in the compasses, and with one leg on *C* make the pole mark (*D*). This must be on the same side of the meridian as *C*. A line from *D* to *E* will cut the meridian in the position of the elevated pole (*P*).

Take the **polar distance** (*D B*) in the compasses, and with one leg on *D* describe a mark on the other side of *N*. Call this mark *F*.

Draw a line from *E* through *F* which will strike the meridian (extended to the Northward) at *G*.

Bisect *G* ⊙ in *H*.

H ⊙ is radius of declination parallel *d* ⊙ *d′*.

EXPLANATION OF THE FIGURE.

(To be written at the examination.)

The circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial.
P the elevated pole.
d ⊙ *d′* the parallel of declination

⊙ the object on the meridian at the time of observation. From the figure it is seen that :—
Z S (90°) − *Z* ⊙ = *S* ⊙, or 90° − zenith distance = altitude.

TO COMPUTE THE MERIDIAN ALTITUDE OF A STAR.

(See Formula on opposite page.)

Write down the latitude by account and underneath it the star's declination. If they have the same names, subtract one from the other; if they have different names, add them together. The result is the approximate meridian zenith distance.

Subtract this from 90° to get (approximately) the true meridian altitude.

Then apply all the usual connections to it in the opposite way to that which you do when correcting an observed altitude. The result is the approximate observed meridian altitude.

Name it N. if the star is bearing North from you, but S. if the star is to the Southward (working below).

Lat. by Account,	44° 14′	N.
Declination of *α Aquilæ*,	8 40·5	N.
Approx. Mer. Zen. Dist.,	35 33·5	N.
	90 0	
Approx. True Alt.,	54 26·5	S.
Refraction,	+ 0·7	
Dip,	+ 4·4	
Ind. Error,	+ 2·0	
Approx. Obs. Mer. Alt.,	54 33·6	S.

Examples for Exercise I.

(1) On 11th January, 1929, the observed meridian altitude of the star *β Tauri* (Nath) was 72° 11·5′ South of the observer, height of eye 20 feet, and index error of sextant 2′ 30″ to subtract. Required the latitude.

(2) On 25th December, 1929, the observed altitude of the star *α Canis Majoris* (Sirius) on the meridian was 51° 58′ North of the observer, height of the eye 28 feet, index error 4′ 00″ to add. Required the latitude.

(3) On 13th January, 1929, the observed meridian altitude of the star *α Geminorum* was 28° 40′ North of the observer, height of eye 22 feet, and index error of sextant 3′ to subtract. Required the latitude.

(4) On 14th March, 1929, the observed latitude of the star *α Leonis* (Regulus) on the meridian was 35° 15′ North of the observer, height of the eye 24 feet, and index error 3′ 30″ to add. Required the latitude.

(5) On 12th August, 1929, in latitude by account 16° 30′ S., longitude 80° E., compute the approximate observed meridian altitude of *α Aquilæ* (Altair) as a guide to setting the sextant for observation, height of eye 27 feet, and index error of sextant 3′ 40″ to subtract.

(6) On 26th April, 1929, in latitude by account 48° 30′ N., Longitude 6° W., compute the approximate observed meridian altitude of *α Lyræ* (Vega) as a guide to setting the sextant for observation, height of eye 33 feet, and index error 1′ 30″ to add.

(7) On 22nd March, 1929, in latitude by account 42° 24′ S., longitude 165° E., compute the approximate observed meridian altitude of the star *α Leonis* (Regulus) as a guide to setting the sextant for observation, height of eye 31 feet, and index error 2′ 30″ to add.

(8) On 7th January, 1929, in latitude by account on the equator, longitude 85° E., compute the approximate observed meridian altitude of the star *α Eridani* (Achernar) as a guide to setting the sextant for observation, height of eye 24 feet, and index error 2′ 00″ to subtract.

MERIDIAN ALTITUDE STAR BELOW THE POLE.

Worked Example I.

(To find the Latitude.)

On 8th April, 1929, in longitude 150° W., the observed meridian altitude of the star ε Ursæ Major (*Alioth*) below the pole was 15° 8′ North of observer, index error 1′ 40″ to add, height of eye 30 feet. Required the latitude.

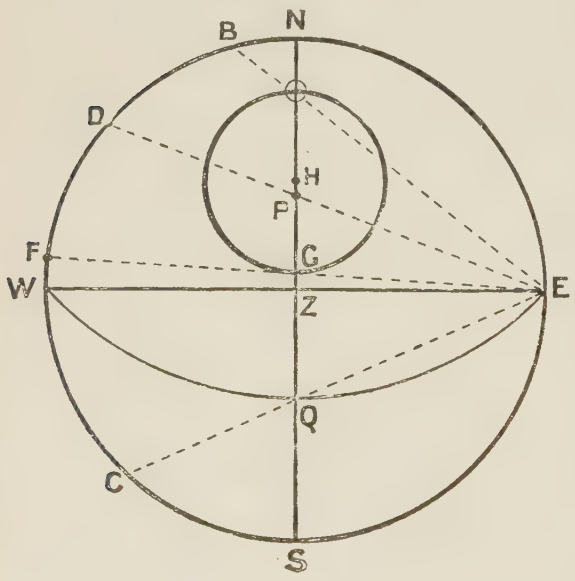
Instructions for Drawing the Figure.

(Not to be written at the examination.)

Describe the large circle, and draw *N Z S* (the observer's meridian), and *W Z E* (the prime vertical).

The altitude being 15° N., measure off 15° from N., and make the mark *B* (the altitude mark).

Given alt, 15° N.
Declination, 56° N.
Polar dist., 34°.



Draw a line from *B* to *E* which will cut the meridian in the position of the object on the meridian below the pole. (⊙ in figure.)

Take the polar distance (34°) in the compasses, and with the point on *B* make the mark *D* (the pole mark). Then *D B* will represent the polar distance.

Now lay off the polar distance in the other direction from *D*, and make the mark *F*. You now have the polar distance laid off both ways from *D* (*D B* and *D F*).

A line from *D* to *E* will cut the meridian at *P* (the pole).

A line from *F* to *E* will cut the meridian at *G*, which is the position of the object when it crosses the meridian above the pole.

Bisect *G* ⊙ in *H*.

With *H* ⊙ as radius describe the small circle which represents the parallel of declination.

Take a chord of 90° in the compasses, and with the point on *D* (the pole mark) describe *C* (the equinoctial mark).

A line from *C* to *E* will cut the meridian at *Q*, which is the point where it is intersected by the equinoctial.

Describe the great circle *W Q E* which represents the equinoctial.

WORKED EXAMPLE I. (*Continued*).

DESCRIPTION OF THE FIGURE.

(To be written at the Examination.)

The large circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial.
P the pole.

The small circle represents the parallel of declination.
⊙ the object on the meridian below the pole.
N ⊙ the altitude.
P ⊙ the polar distance.

Z being the observer's zenith, and *W Q E* the equinoctial, *Z Q* represents the latitude, and *P Z* the co-latitude.

From *N* (the North point of the horizon) to *Z* (the observer's zenith) is 90° therefore if *P Z* represents the co-lat., *P N* must represent the lat., as also does *Z O*.

From the figure it is seen that :—

N ⊙ + P ⊙ = P N,

or, altitude + polar dist. = latitude.

	°	′	
Star's declination,	56	20·7	N.
	90	0	
Polar distance,	33	39·3	

	°	′	
Obs. alt.,	15	8·0	N.
Ind. error,	+	1·7	
	15	9·7	
Dip,	−	5·4	
	15	4·3	
Ref.,	−	3·5	
True alt.,	15	0·8	
Polar dist.,	33	38	
Latitude,	48	38·8	N.

Note that when the object is on the meridian below the pole it always bears North in North latitude, and South in South latitude. In other words, the latitude always has the same name as the bearing of the object.

MERIDIAN ALTITUDE STAR BELOW THE POLE.

Worked Example II.

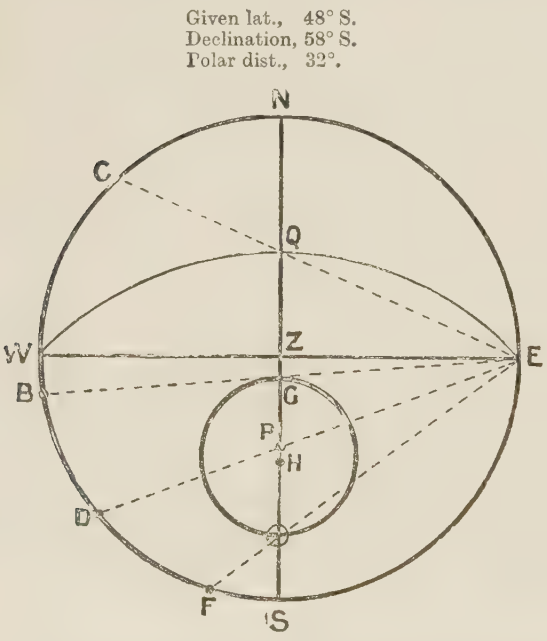
(To find the altitude.)

On 22nd June, 1929, in latitude by account 48° 04′ S., longitude 120° E., compute the approximate observed meridian altitude of the star α Eridani (*Achernar*) below the pole as a guide to setting the sextant for observation. Index error of sextant 1·5′ to subtract. Height of eye 27 feet.

Instructions for Drawing the Figure.

(Not to be written at the examination.)

Describe the large circle to represent the observer's rational horizon. Draw *N Z S* (the observer's meridian), and *W Z E* (the prime vertical).



As the latitude by account is about 48° S., the altitude of the pole is approximately 48° S. Measure off an arc of 48° from S., and make the mark *D* (the pole mark).

Draw a line from *D* to *E*. This will intersect the meridian at *P*, which is the position of the pole.

Take a chord of 90° in the compasses, and with the point on *D* (the pole mark) make the mark *C* (the equinoctial mark).

Draw a line from *C* to *E*. This will intersect the meridian at *Q*.

Describe the great circle *W Q E*, which represents the equinoctial.

Take the polar distance (32°) in the compasses, and lay it off both ways from *D* (the pole mark), reaching the points *B* and *F*.

A line from *B* to *E* will indicate the point (*G*) where the circle of declination crosses the meridian above the pole.

A line from *F* to *E* will indicate the point (⊙) where the circle of declination crosses the meridian below the pole. This will be the position of the object of which we are required to compute the altitude.

Bisect *G* ⊙ in *H*.

With *H* ⊙ as radius, describe the small circle which represents the declination parallel.

WORKED EXAMPLE II. (*Continued*).

DESCRIPTION OF THE FIGURE.

(To be written at the Examination.)

The large circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
$N\ Z\ S$ the observer's meridian.
$W\ Z\ E$ the prime vertical.
$W\ Q\ E$ the equinoctial.
P the pole.
Small circle the parallel of declination.
$\odot$ the object on the meridian below the pole.
$Z\ Q$ the latitude.
$P\ Z$ the co-latitude.
$P\ S$ also represents the latitude.
$P\ \odot$ the polar distance.
$S\ \odot$ the altitude.

From S (the South point of the horizon) to Z (the observer's zenith) is 90°, therefore if $P\ Z$ represents the co-latitude, $P\ S$ must represent the latitude.

From the figure we see that : –

$P\ S - P\ \odot = S\ \odot$,

or, latitude — polar distance = altitude.

	°	′	
Star's declination, . . .	57	35·5 S.	
	90	0 .	
Polar distance, . . .	32	24·5	
Lat. by account, . .	48	4·0 S.	$= P\ S$
Polar distance, . .	32	24·5	$= P\ \odot$
Approx. true alt., . .	15	39·5	$= S\ \odot$
Refraction, . . .	+	3·3	
Dip, ...	+	5·1	
Index error, . . .	+	1·5	
Approx. obs. mer. alt., .	15	49·4 S.	

It will be noted that the procedure when drawing the figure for this problem is somewhat different from that adopted when drawing the previous one. The reason is that the figure must be drawn (to obtain the formula) before the problem is worked out. In the first example **the altitude was given** and we had to find the latitude. In this one **the latitude is given** and we have to find the altitude.

MERIDIAN ALTITUDE STAR BELOW THE POLE.

Examples for Exercise I.A.

(1) On 16th January, 1929, in longitude 20° E., the observed meridian altitude of the star "*α Argus*" (Canopus) below the pole was 14° 12·5′ bearing South. Index error 1′ 20″ to add, height of eye 32 feet. Required the latitude.

(2) On 5th March, 1929, in longitude 20° W., the observed altitude of the star "*α Cygni*" (Deneb) when on the meridian below the pole was 17° 40′ 20″ North of observer, index error 2′ to subtract, height of eye 26 feet. Required the latitude.

(3) On 22nd December, 1929, in latitude by account 49° 52′ N., longitude 170° E., compute the approximate observed meridian altitude of the star "*α Ursæ* Major" (Dubhe) below the pole. The sextant has an index error of 1′ 50″ to subtract, height of eye 30 feet.

(4) On August 28th, 1929, in latitude by account 51° 10′ S., longitude 160° W., compute (approximately) the observed altitude of the star "*α Triang. Aust.*" when on the meridian below the pole, as a guide to setting the sextant for observation. Index error of sextant 1·5 to add, height of eye 29 feet.

LONGITUDE BY CHRONOMETER BY ALTITUDE OF A STAR.

This is worked in the same way as the sun chronometer until the hour-angle is obtained, the star's polar distance and zenith distance being used instead of that of the sun.

Study the worked examples and set the work out in the following order.

Find the Greenwich mean time from the chronometer time as when working the sun chronometer.

Take out from page 1 (or 2) of the month in *The Nautical Almanac* the star's **Right Ascension** and **Declination**, and from the latter find the star's **Polar Distance.**

Copy down from pages 3 to 6 of the month **the value of R.** which is given for the 2 hours which are next lower than your G.M.T., and correct it for the remaining hour (if any) and minutes. The correction is taken from the card of " Proportional Parts " given with this book, and, as stated on the card, **must always be added.** A similar card is given with " Brown's " and the abridged edition of the official *Nautical Almanac.*

Correct the observed altitude, and find the star's zenith distance.

Subtract the latitude from 90° to get the co-lat.

Calculate the hour angle by means of the Haversine formula, and then :—

If the star is East of the meridian, subtract its H.A. from the star's R.A.

If the star is West of the meridian, add its H.A. to the star's R.A. (should the sum exceed 24 hours, reject 24 hours).

The result in both cases is the R.A.M., or Sidereal time at ship.

From the R.A.M. subtract the corrected value of R., borrowing 24 hours if necessary.

The remainder of the ship's mean time (S.M.T.) to which prefix the same date as the question in all cases.

Underneath the S.M.T. write down the G.M.T. The difference between them is the longitude in time. Turn it into arc, and name it in the same way as when finding longitude by the sun, *i.e.*,

Greenwich time least, longitude East.

Greenwich time best, longitude West.

Worked Example I.

On 27th June, 1929, in latitude by account 12° 18′ S., longitude by account 126° W., the observed altitude of the star "*α Piscis Australis*" (Fomalhaut), east of the meridian was 21° 19·8′, no index error, height of eye 21 feet, time by a chronometer (28th June) 08 h. 05m. 40s., which was fast for mean noon at Greenwich, 30th March, 1929, 4m. 16s., and losing ·4s. daily. Required the longitude by chronometer.

The figure is exactly the same, and is drawn in precisely the same way as that for "Chronometer and Azimuth" in the Second Mate's work.

The fact that the azimuth is not worked makes no difference whatever.

FIGURE FOR WORKED EXAMPLE I.

As the latitude is 12° S., the pole will be South of the observer, and will have an altitude of 12°. Make a mark on the horizon (West of the meridian) 12° from S. A line from this pole mark drawn to *E* will intersect the meridian in the position of the pole (*P*).

Take a chord of 90° in the compasses, and with the point on the pole mark describe the equinoctial mark on the same side of the meridian as the pole mark. A straight line drawn from the equinoctial mark to *E* will cut the meridian in the position of the equinoctial (point *Q*). Draw *W Q E* the equinoctial.

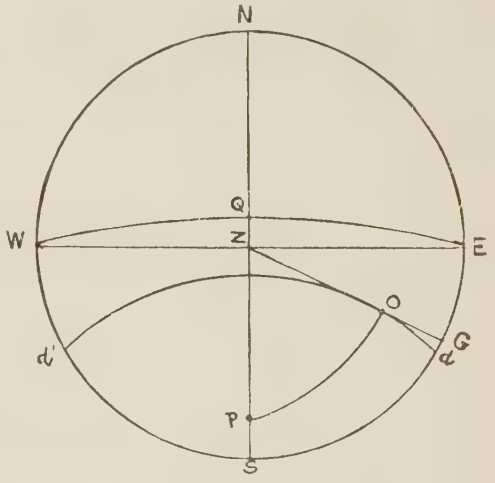
Take the **polar distance** (60°) in the compasses, lay it off **both ways** from the pole mark, and put the declination parallel in by the methods you used in "Amplitudes" and "Chronometer and Azimuth."

As an object has an altitude of 21° lay off an arc of 21° from N., and make the altitude mark on the horizon, West of the meridian. A straight line from this altitude mark to *E* will cut the meridian in the position of a "circle of equal altitude" of 21°. With the point of your compasses on *Z*, describe this circle of equal altitude which will cross the declination parallel in the position of the object at the time of observation, call it *O*.

Draw *P O*, which represents the polar distance, and which is also the hour circle passing through the object.

Read "General Remarks on Figure Drawing."

Given Lat. 12° S.
Decl. 30° S.
Alt. 21°.
Object E. of mer.



Draw *Z O G*, which is a vertical circle passing through the object.

EXPLANATION OF THE FIGURE.

(To be written at the examination.)

The circle represents a stereographic projection of the celestial concave on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial.
P the pole.
d O d′ the parallel of declination.
O the object.
O G the altitude.
Z O the zenith distance.
P O the polar distance.
P Z the co-lat.
Z P O the star's hour angle.

Worked Example I.

To find the G.M.T.

	d.	h.	m.	s.
Time by Chrontr.	28	08	05	40
Fast, . .	—		4	16
	28	08	01	24
Acc. rate, .	+			36
M.T.G., . .	28	08	02	00

To Find Accumulated Rate.

	days.
Noon Mar. 30 to noon Mar. 31 =	1
,, Mar. 31 ,, April 30 =	30
,, April 30 ,, May 31 =	31
,, May 31 ,, June 27 =	27
,, June 27 to 28d. 8h. = 20h. =	·8
	89·8 days.
Daily rate,	·4 secs.
Acc. rate,	35·92 secs.

	h.	m.	s.
Star's R.A., .	22	53	45

Star's decl., .	29°	59·7′ S.
	90	00
Polar dist., .	60	00·3 = *P O*

To Correct R.

	h.	m.	s.
28d. 8h.	=18	23	43·4
Corr. for 2m., .	+		0·3
R. corrected .	18	23	43·7

	°	′
Obs. alt., . .	21	19·8
Dip, . .	—	4·5
	21	15·3
Ref., . .	—	2·4
True alt., .	21	12·9
	90	00
Zen. dist. (*p*), .	68	47·1 = *Z O*

	°	″
Lat., .	12	18 S.
	90	0
Co-lat., .	77	42 = *P Z*

	°	′
P Z =	77	42
P O =	60	0·3
P Z ~ *P O* =	17	41·7

Given in triangle *P Z O*, the sides *P Z*, *P O*, and *Z O* (*p*)

Required angle *P* (the hour angle)

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (P Z \sim P O)}{\sin P Z \sin P O}$$

	°	′	
p =	68	47·1	nat. hav. 0·31907
(*P Z* ~ *P O*) =	17	41·7	nat. hav. 0·02366
			nat. hav. 0·29541
			log hav. 9·47043
P Z =	77	42	log cosec 0·01009
P O =	60	00·3	log cosec 0·06245
			log hav. 9·54297

4h. 49m. 45s.

	h.	m.	s.	
Easterly hour angle, . .	4	49	45	*1
Star's R.A., . . .	22	53	45	
R.A.M. (sid. time), . .	18	04	00	
R., ...	—18	23	44	
S.M.T., ...	27	23	40	16 *2
G.M.T., ...	28	08	02	00
Long. in time, . . .	8	21	44	
	60			
	4) 501	44		
Longitude, . . .	125	26 W.		

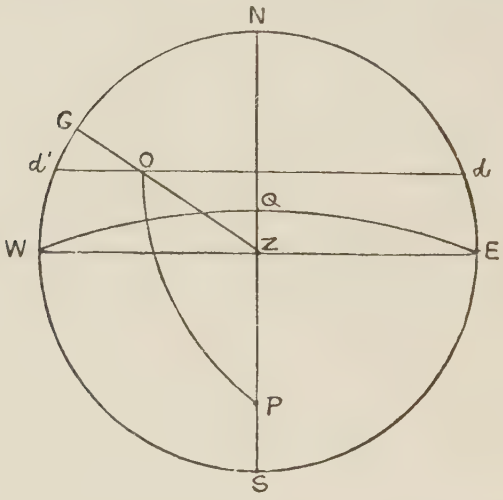
(*1) The star being East of the meridian, its hour angle is subtracted from the star's R.A. to find the R.A.M.

(*2) Having found the S.M.T., it is always given the same date as the question.

Worked Example II.

On 24th March, 1929, in latitude by account 19° 42′ S., longitude by account 89° 30′ E., the observed altitude of the star "*α Bootis*" (Arcturus) west of the meridian was 25° 01′, height of eye 27 feet, time by a chronometer (23rd March) 23h. 44m. 36s., which was fast for mean noon at Greenwich, 28th February, 1929, 01m. 00s., and gaining 3·27s. daily. Required the longitude by chronometer.

FIGURE FOR WORKED EXAMPLE II.



Given Lat. 20° S.
Decl. 20° N.
Alt. 25°.
Object W. of mer.

The elevated pole and the equinoctial are put in by exactly the same means as in the previous example.

When the latitude and declination are the same value and of opposite name, the parallel of declination **must be shown as a straight line.**

The position of the object at the time of observation is found by means of a "circle of equal altitude" of 25°. This will be found to cut the parallel of declination at *O*, thus indicating the position of the object.

EXPLANATION OF THE FIGURE.

(To be written at the examination.)

The circle represents a stereographic projection of the celestial concave in the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial.
P the pole.
d' O d the parallel of declination.
O the object at the time of observation.
G O the altitude.
O Z the zenith distance.
P O the polar distance.
P Z the co-lat.
Z P O the star's hour angle.

Worked Example II.

To find the G.M.T.

	d.	h.	m.	s.
Time by chron.,	23	23	44	36
Error fast, . —			1	0
	23	23	43	36
Acc. rate gained,			1	17
G.M.T., . .	23	23	42	19

To Find the Accumulated Rate.

	days.
Noon Feb. 28 to noon Mar. 23	= 23
,, Mar. 23 to chron. time = 12h.	= ·5
	23·5
Daily rate,	3·27
	1645
	470
	705
	6,0) 7,6·845
Acc. rate,	1m. 17s.

	h.	m.	s.
Star's R.A., .	14	12	26
Star's decl., .	19°	32·8′	N.
	90	00	
Polar dist., .	109	32·8	= P O

To correct R.

	h.	m.	s.
23d. 22h. .	= 12	03	35·5
Corr. 1h. 42m. .	+		16·8
R. corrected, .	12	03	52·3

	°	′
Obs. alt., .	25	01
Dip, . .	—	5·1
	24	55·9
Ref., . .		2·0
True alt., .	24	53·9
	90	00
Zen. dist. (p), .	65	06·1 = Z O

	°	′
Latitude, .	19	42 S.
	90	0
Co-lat., . .	70	18 = P Z

	°	′
P Z =	70	18
P O =	109	32·8
P Z ~ P O =	39	14·8

Given in triangle $P\,Z\,O$, the sides $P\,Z$ (the co-lat.), $P\,O$ (the polar dist.) and $Z\,O$ (p) (the zen. dist.)

Required to find angle P (the hour angle)

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (P\,Z \sim P\,O)}{\sin P\,Z \sin P\,O}$$

	°	′	
p =	65	6·1	nat. hav. 0·28950
$P\,Z \sim P\,O$ =	39	14·8	nat. hav. 0·11278
			nat. hav. 0·17672
			log hav. 9·24728
$P\,Z$ =	70	18·0	log cosec 0·02619
$P\,O$ =	109	32·8	log cosec 0·02578
			log hav. 9·29925

3h. 32m. 3s.

	h.	m.	s.	
Westerly hour angle, . .	3	32	3	*1
Star's R.A., ...	14	12	26	
R.A.M. (sid. time), . . .	17	44	29	
R., ...	— 12	03	52	
S.M.T., ...	24	05	40	37
G.M.T., ...	23	23	42	19
Long. in time, ...	5	58	18	
		60		
	4) 358	18		
Longitude, ...	89	34	30 E.	

(*1) The star being West of the meridian, its hour angle must be added to the star's R.A. to find the R.A.M.

Examples for Exercise II.

(1) On 12th January, 1929, in latitude by account 46° 38′ S., longitude by account 137° E., the observed altitude of the star "*α Canis Majoris*" (Sirius) west of the meridian was 23° 16′, index error 2′ to subtract, height of eye 21 feet, time by a chronometer (11th January) 19h. 02m. 40s., which was slow for Mean noon at Greenwich, 24th November, 1928, 3m. 18s., and gaining 1·1s. daily. Required the longitude by chronometer.

(2) On 12th May, 1929, in latitude by account 23° 46′ N., longitude by account 29° 30′ W., the observed altitude of the star "*α Virginis*" (Spica) east of the meridian was 37° 58′, index error 2′ 20″ to subtract, height of eye 28 feet, time by a chronometer 21h. 16m. 14s., which was slow for Mean noon at Greenwich, 6th April, 1929, 2m. 12s., and losing 1·7s. daily. Required the longitude by chronometer.

(3) On 22nd March, 1929, in latitude by account 34° 29′ N., longitude by account 179° 45′ W., the observed altitude of the star "*α Tauri*" (Aldebaran) after passing the meridian was 39° 50·5′, height of eye 19 feet, time by a chronometer (23rd March) 08h. 02m. 57s., which was fast for Mean noon at Greenwich, 17th January, 1929, 0m. 34s., and gaining 2·2s. daily. Required the longitude by chronometer.

(4) On 24th June, 1929, in latitude by account 47° 53′ S., longitude by account 178° W., the observed altitude of the star "*α Piscis Australis*" (Fomalhaut) west of the meridian was 54° 10·5′, height of eye 21 feet, index error 1′ 10″ to add, time by a chronometer 19h. 18m. 58s., which was slow for Mean noon at Greenwich, 29th March, 1929, 1m. 13s., and gaining 1·0s. daily. Required the longitude by chronometer.

(5) On 24th September, 1929, in latitude by account 16° 38′ N., longitude by account 173° E., the observed altitude of the star "*α Aquilæ*" (Altair) west of the meridian was 34° 29′, height of eye 20 feet, no index error, time by a chronometer 11h. 42m. 25s., which was slow for Mean noon at Greenwich, 11th May, 1929, 2m. 36s., and losing 1·8s. daily. Required the longitude by chronometer.

(6) On 23rd December, 1929, in latitude by account 41° 14′ S., longitude by account 5° W., the observed altitude of the star "*α Orionis*" (Betelguese) before reaching the meridian was 16° 21′, time by a chronometer 20h. 02m. 30s., which was fast for Mean noon at Greenwich, 28th November, 1929, 3m. 18s., and losing 3·3s. daily. Height of eye 25 feet. Required the longitude by chronometer.

TO FIND THE RIGHT ASCENSION OF THE MERIDIAN (R.A.M.) OR SIDEREAL TIME AT SHIP.

As the R.A.M. is used in most of the following star problems it is important that the method of finding it should be thoroughly understood. A few examples are, therefore, given here.

IF MEAN TIME AT SHIP IS GIVEN.

Write down the S.M.T. ; apply the longitude in time to it, **East subtract, West add ;** the result is the G.M.T.

Correct R. taken from *The Nautical Almanac* for the G.M.T., and to it add the S.M.T. **The sum is the R.A.M.**

IF GREENWICH MEAN TIME IS GIVEN.

Write down the G.M.T., and to it apply the longitude in time, East add, West subtract ; **the result is the S.M.T.**

Correct R. taken from *The Nautical Almanac* for the G.M.T., and to it add the S.M.T. **The sum is the R.A.M.**

IF APPARENT TIME AT SHIP IS GIVEN.

Write down the S.A.T., and to it apply the longitude in time (E. —, W. +), the result is the G.A.T.

Correct E. and R. from *The Nautical Almanac*, using the G.A.T. It is not strictly correct to use the G.A.T., as everything taken from *The Nautical Almanac* should be corrected (if correction is necessary) for G.M.T. The result, however, is practically the same, and is quite good enough for all ordinary purposes and for the examinations.

Write down the H.A.T.S. This is the S.A.T. + 12 hours if less than 12 hours, but — 12 hours if over 12 hours.

From the H.A.T.S. subtract E., borrowing 24 hours if necessary ; the remainder is the S.M.T.

To the S.M.T. add R., **the sum is the R.A.M.**

If the R.A.M. exceeds 24 hours, reject 24 hours in all cases.

Worked Example I.

On 8th January, 1929, at 05h. 47m. Mean time at ship in longitude 136° 30′ E. Find the R.A.M.

Long. E.		d.	h.	m.	s.
136° 30′	S.M.T.,	8	05	47	00
4	Long. E., —		9	6	0
6,0)54,6 0	G.M.T.,	7	20	41	00
9h. 6m. 0s.					

d.	h.		h.	m.	s.
R. 7	20		07	07	34·1
Corr. 41m.,		+			6·7
R. corrected,			07	07	40·8
S.M.T.,		+	05	47	00
R.A.M.,			12	54	40·8

Worked Example II.

On 23rd December, 1929, in longitude 176° 15′ W., when a chronometer indicated 16h. 06m. 31s., correct Mean time at Greenwich. Find the R.A.M.

Long. W.		d.	h.	m.	s.
176° 15′	G.M.T.,	23	16	06	31
4	Long. W., —		11	45	0
6,0)70,5 0	S.M.T.,	23	04	21	31
11h. 45m. 0s.					

d.	h.		h.	m.	s.
R. 23	16		06	06	49·3
Corr. 6·5m.,		+			1·1
R. corrected,			06	06	50·4
S.M.T.,		+	04	21	31
R.A.M.,			10	28	21·4

Worked Example III.

On 22nd March, 1929, at 18h. 17m. Apparent time at ship in longitude 1° 30′ W. Find the R.A.M.

Long. W.		d.	h.	m.	s.
1° 30′	S.A.T.,	22	18	17	00
4	Long. W., +			6	0
6m. 0s.	G.A.T.,	22	18	23	00

d.	h.		h.	m.	s.
E. 22	18		11	53	00·8
Corr. 23m.,		+			·3
E. corrected,			11	53	01·1

d.	h.		h.	m.	s.
R. 22	18		11	58	59·5
Corr. 23m.,		+			3·8
R. corrected,			11	59	03·3

	h.	m.	s.
H.A.T.S.,	6	17	00
E.,	−11	53	01
S.M.T.,	18	23	59
R.,	+11	59	03
R.A.M.,	06	23	02

Examples for Exercise III.

Find the R.A.M. in the following examples :—

(1) 1929.—September 27th, at 03h. 26m. Mean time at ship, in longitude 136° 40′ E.

(2) 1929.—April 19th, at 01h. 59m. Apparent time at ship, in longitude 173° 13′ W.

(3) 1929.—January 6th, at 20h. 58m. 25s. Mean time at ship, in longitude 55° 11′ W.

(4) 1929.—March 22nd, at 05h. 10m. Apparent time at ship, in longitude 54° 30′ E.

(5) 1929.—June 14th at ship, at 22h. 38m. 20s. Mean time at Greenwich, in longitude 42° 20′ W.

(6) On 26th December, 1929, in longitude by account 125° W., time by a chronometer 13h. 12m. 20s., which was 1m. 28s. slow for G.M.T.

TO DETERMINE WHAT BRIGHT STARS ARE NEAR THE MERIDIAN.

In this problem, Candidates are required to determine what bright stars are within an hour or more (as stated in the question) of the observer's meridian at any given time ; also to find the hour angle of each star, and state whether they cross the meridian to the North or South of the observer's zenith.

Right Ascension is reckoned from the meridian of the First Point of Aries **Eastward** in a similar manner to the way in which East longitude is reckoned from the meridian of Greenwich. Therefore, if a star's R.A. is **greater** than the R.A.M., that star must be to the **Eastward** of the meridian ; if its R.A. is **less** than the R.A.M. it is to the **Westward** of the meridian. R.A. is reckoned in time from 0 to 24 hours.

Magnitude of Stars.—The brightness of a star is indicated by its magnitude. The **less** the number denoting the magnitude the **brighter** the star is. Thus a star of magnitude 2·0 is brighter than one of magnitude 2·1.

Stars Below the Horizon.—If the declination of a star and the latitude are of **different** names and their **sum** (which is the zenith distance) exceeds 90°, that star is below the horizon, and, therefore, not visible in that latitude.*

TO PICK THE STARS OUT FROM THE ALMANAC.

FIND THE R.A.M.

From the R.A.M. **subtract** the interval of time given in the question and call the remainder the **first** R.A.

To the R.A.M. **add** the given interval and call the result the **second** R.A. (Working to the nearest minute is good enough.)

Open the *Nautical Almanac* at page 1 of the month, begin at the **first** R.A. and take out all the stars of the magnitude stated in the question or brighter until you come to the **second** R.A., at which you must stop. This will give you the stars on **both** sides of the meridian. For stars on the East side only, *see* Worked Example II.

Stars below the Horizon must not be put down.

If the star's declination is **North** of the latitude the star will cross the meridian **North** of the zenith, and *vice versâ*.

To find the Hour Angle of a Star.—Put down the R.A.M., and under it the star's R.A. ; **their difference is the Star's Hour Angle.**

To name the Hour Angle :—

If the Star's R.A. has been subtracted from the R.A.M. the remainder is the H.A West.

If the R.A.M. has been subtracted from the Star's R.A., the remainder is the H.A. East.

If an Hour Angle exceeds 12 *hours it should be subtracted from* 24 *hours and its name changed.*

* It would be better for practical purposes to substitute 85° for the 90° in this rule, for stars can very seldom be observed if their altitude is below 5°—that is, zenith distance over 85°. To find the stars actually above the horizon, however, 90° must be used.

Worked Example I.

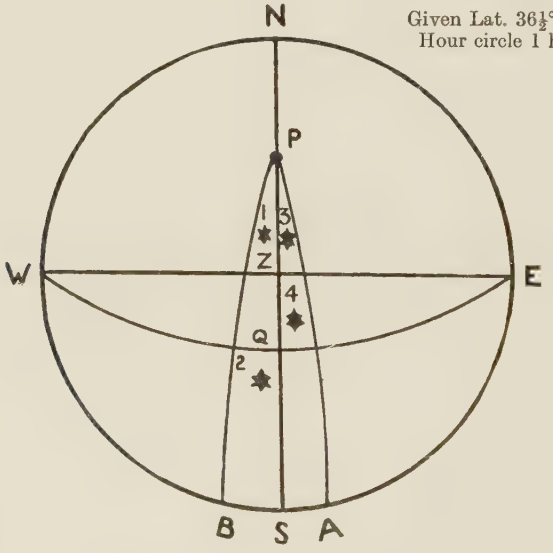
Supposing you are not familiar with the stars, and wish to take an observation, find the names of the stars of magnitude 2·0 or brighter that are within one hour East and West of your meridian, above the pole and above the horizon, at 06h. 30m. Mean time at ship on January 9th, 1929, the latitude being 36° 30′ N. and the Long. 48° 18′ W. Find also the approximate hour angle of each of these stars, stating whether they are East or West of your meridian, and also whether to the North or South of your zenith when passing the meridian.

FIGURE FOR WORKED EXAMPLE I.

The circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the zenith, *P* the pole.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial.

As we require the stars within 1 hour East and West of the meridian, an hour circle is drawn 1 hour each side of the observer's meridian. The required stars must lie between these two hour circles. They are shown in the diagram in their approximate positions which are determined by their declination and hour angle, and distinguished by numbers corresponding to those placed against them as they were taken out from the Almanac and written down on the opposite page.



P A the 1 hour Easterly hour circle.
P B the 1 hour Westerly hour circle.

These hour circles are described by exactly the same methods as those used in the " Time Azimuth " examples.

Worked Example I.

Long. W. 48° 18′ = 4

6,0) 193 12

3h. 13m. 12s.

	d.	h.	m.	s.
S.M.T., . .	.= 9	06	30	0
Long. in time W.,	.+	3	13	12
G.M.T., . . .	.= 9	09	43	12

Latitude, 36° 30′ N.

	d.	h.	m.	s.
R. 9	08	. .	.=07	13	29·0
Corr. 1h. 43m.,	.	.	.+		16·9
R. corrected,	.	.	07	13	45·9
S.M.T.,	.	.	.+06	30	00·0
R.A.M.,	.	.	13	43	45·9

	h.	m.
R.A.M., . . .	=13	44
Interval W., . .	− 1	0
1st R.A., . .	12	44

	h.	m.
R.A.M., . . .	=13	44
Interval E., . .	+ 1	0
2nd R.A., . .	14	44

Now turn to page 1 of the month in the *Nautical Almanac*, and pick out the stars of the required magnitude whose Right Ascensions come in between 12h. 44m. and 14h. 44m. Write them down in the order in which they occur, arranging them as shown below.

1. *ε Ursæ Maj.*

Magnitude, . .	1·7	
Declination, . .	56°	N.
	h.	m.
R.A.M., . .	13	44
Star's R.A., . .	12	51
Hour angle, . .	0	53 W.

Has crossed North.

2. *α Virginis.*

Magnitude, . .	1·2	
Declination, . .	11°	S.
	h.	m.
R.A.M., . .	13	44
Star's R.A., . .	13	21
Hour angle, . .	0	23 W.

Has crossed South.

3. *η Ursæ Maj.*

Magnitude, . .	1·9	
Declination, . .	50°	N.
	h.	m.
R.A.M., . .	13	44
Star's R.A., . .	13	45
Hour angle, . .	0	1 E.

Will cross North.

4. *α Bootis.*

Magnitude, . .	0·2	
Declination, . .	20°	N.
	h.	m.
R.A.M., . .	13	44
Star's R.A., . .	14	12
Hour angle, . .	0	28 E.

Will cross South.

The stars *β Centauri* and *α Centauri* are omitted because their declination being of a **different** name to the latitude, and the sum in each case exceeding 90° we know that they are below the horizon.

Worked Example II.

On December 27th, 1929, in latitude 38° 42′ S., longitude 136° 42′ W., find the names of the stars not less bright than the first magnitude that are within 1½ hours East of the meridian above the pole and above the horizon. Time by chronometer (28th December) 08h. 50m. 30s., which was 11m. 18s. slow on Mean time at Greenwich. Find the approximate hour angle of each of these stars, and state if they cross the meridian to the North or South of your zenith.

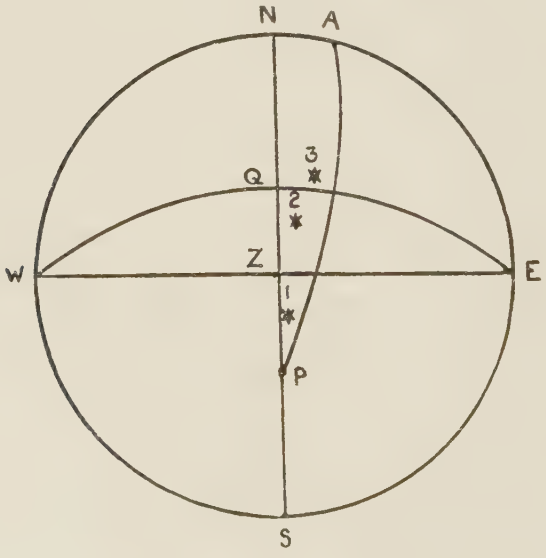
FIGURE FOR WORKED EXAMPLE II.

In this question, as we are only asked for stars 1½ hours **East** of the meridian, stars to the West of the meridian are not required, and a Westerly hour circle is not put in.

Let the circle represent a stereographic projection of the celestial sphere on the plane of the rational horizon.

Z the zenith, *P* the pole.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial.
P A the 1½ hours Easterly hour circle.

Given Lat 39° S.
Hour circle 1½ hrs.



The stars are shown in their approximate positions, numbered 1, 2, and 3, as on following page.

The hour circle is described by exactly the same methods as that used in the " Time Azimuth " examples.

Worked Example II.

Long. W.			d.	h.	m.	s.		d.	h.			h.	m.	s.
136°	42′	Time by chrontr.,	28	08	50	30	R.	28	08			06	25	13·2
	4	Slow,	+		11	18	Corr. 1h. 2m.,				+			10·2
6,0)54,6	48	G.M.T.,	28	09	01	48	R. corrected,					06	25	23·4
9h. 6m. 48s.		Long. W.,	−	9	6	48	S.M.T.,				+	23	55	00
		S.M.T.,	27	23	55	00	R.A.M.,					06	20	23

Latitude, 38° 42′ S.

	h.	m.
R.A.M.,	6	20
Interval, +	1	30
	7	50

When, as in this question, the stars East of the meridian only are required, do not subtract the interval from the R.A.M., but begin to look up the stars whose Right Ascensions are **greater** than the R.A.M., and stop when you get to the interval added to the R.A.M.

Looking in page 1 of the month in the *Nautical Almanac* and in this book, you will find that the following stars are the ones which are required :—

1. *α Argus* (*Canopus*).

Magnitude, — 0·9
Declination, 53° S.

	h.	m.
R.A.M.,	6	20
Star's R.A.,	6	22
Hour angle,	0	2 E.

Will cross South.

2. *α Can. Maj.* (Sirius).

Magnitude, — 1·6
Declination, 17° S.

	h.	m.
R.A.M.,	6	20
Star's R.A.,	6	42
Hour angle,	0	22 E.

Will cross North.

3. *α Can. Min.* (Procyon).

Magnitude, 0·5
Declination, 5° N.

	h.	m.
R.A.M.,	6	20
Star's R.A.,	7	36
Hour angle,	1	16 E.

Will cross North.

Notice the magnitudes of Canopus and Sirius. The minus sign prefixed to them indicates that they are brighter than magnitude 0, and, therefore, both are brighter than magnitude 1·0. These two stars are the only ones with a minus magnitude.

When the magnitude of a star is written 1·0 — 1·4 it means that its magnitude varies between 1·0 and 1·4. If the magnitude required in any example comes in between the two given magnitudes, write the star down and mark it "magnitude variable 1·0 — 1·4," or whatever it may be.

Worked Example III.

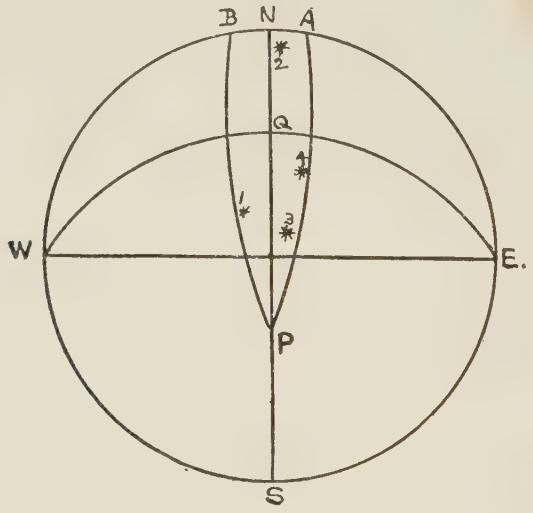
On 24th June, 1929, at 05h. 36m., Apparent time at ship, in Lat. 54° 30′ S., Long. 156° 42′ E., find the names of the stars up to magnitude of 2·5 that are within one hour East and West of the meridian above the pole and above the horizon. Find also the approximate hour angle of each star, and state if to the North or South of the zenith when passing the meridian.

FIGURE FOR WORKED EXAMPLE III.

As the stars within 1 hour of the meridian on each side are asked for, an hour circle is drawn 1 hour on each side of the observer's meridian.

The stars are then put in according to their declination and hour angle, the position of each one being estimated approximately by the eye.

Let the circle represent a stereographic projection of the celestial sphere on the plane of the rational horizon.



N Z S the observer's meridian, *Z* the zenith.

W Z E the prime vertical, *P* the pole.

W Q E the equinoctial.

P A the 1 hour Easterly hour circle.

P B the 1 hour Westerly hour circle.

The stars (numbered 1 to 4 as on opposite page) are shown in their respective positions between the two hour circles.

The hour circles are described by exactly the same methods as those used in the "Time Azimuth" examples.

Worked Example III.

Long. E.
156° 42′
4

60) 626 48

h. m. s.
10 26 48

	d.	h.	m.	s.
S.A.T., . . .	24	05	36	00
Long. E., . .	—	10	26	48
G.A.T., . . .	23	19	09	12

	d.	h.		h.	m.	s.
E.	23	18	. . .	11	58	02·0
Corr. 1h. 9m.,			. —			·6
E. corrected,			. .	11	58	01·4

	d.	h.		h.	m.	s.
R.	23	18	. . .	18	05	39·2
Corr. 1h. 9m.,			. +			11·3
R. corrected,			. .	18	05	50·5

	h.	m.	s.
H.A.T.S., . . .	17	36	00
E., . . . —	11	58	01
S.M.T., . . .	05	37	59
R., . . . +	18	05	51
R.A.M., . . .	23	43	50

	h.	m.		h.	m.
R.A.M., .	23	44		23	44
—	1	00	+	1	00
1st R.A., .	22	44	2nd R.A., .	00	44

(1) *Fomalhaut. Mag.* 1·3.

	h.	m.	
R.A.M., . .	23	44	
Star's R.A., .	22	54	
Hour angle, .	0	50	W.

Has crossed North.

(2) *α Andromedæ. Mag.* 2·2.

	h.	m.	
R.A.M., . .	23	44	
Star's R.A., .	00	05	
Hour angle, .	0	21	E.

Will cross North.

(3) *α Phœnicis. Mag.* 2·4

	h.	m.	
R.A.M., . .	23	44	
Star's R.A.. .	00	23	
Hour angle, .	0	39	E.

Will cross North.

(4) *β Ceti. Mag.* 2·2.

	h.	m.	
R.A.M., . .	23	44	
Star's R.A., .	00	40	
Hour angle, .	0	56	E.

Will cross North.

In this example the second R.A. came over 24 hours, the 24 being rejected.

Begin to look out the stars at the first R.A. and proceed to the end ; then start again at the beginning and go as far as the second R.A.

The star *α Cassiopeiæ* has been omitted, being below the horizon.

Examples for Exercise IV.

(1) Supposing you are not familiar with the stars and wish to take an observation find the names (from the *Nautical Almanac*) of the stars not less bright than magnitude 2·5 that will be within 1½ hours East and West of your meridian, above the pole and above the horizon at about 03h. 40m. Apparent time at ship, on 10th January, 1929, in latitude 40° S., longitude 43° 20′ W. Required also approximately the hour angle of each of the stars, and state also whether they will be to the North or South of your zenith when passing the meridian.

(2) Find the names (from the *Nautical Almanac*) of the stars of the second magnitude or brighter that are within 1h. 45m. of your meridian, above the pole and above the horizon, on 19th March, 1929, at ship in latitude 19° 40′ S., longitude 167° 15′ W. Time by chronometer 15h. 39m. 10s., which was 1m. 8s. slow for Mean time at Greenwich. Required also, approximately, the hour angle, etc. (as above).

(3) Find the names of the stars given in the *Nautical Almanac* that are within 1½ hours East of your meridian, above the pole and above the horizon at 05h. 40m. Mean time at ship on April 19th, 1929, in latitude 54° S., longitude 107° W. Find also, approximately, the hour angle, etc. (as above).

(4) On 11th May, 1929, at 07h. 40m. Apparent time at ship in latitude 50° S., longitude 40° E. Find the names of the stars given in the *Nautical Almanac* that are within three hours East of your meridian above the pole and above the horizon. Required also, approximately, the hour angle of each star, etc. (as above).

(5) Find the names (from the *Nautical Almanac*) of the stars brighter than magnitude 2·4 that will be within one hour East and West of your meridian, above the pole and above the horizon, at 00h. 30m. Mean time at ship on 23rd September, 1929, in latitude 35° 20′ N., longitude 155° W. Required also, approximately, the hour angle, etc. (as above).

(6) On 20th September, 1929, at ship, when a chronometer indicated 14h. 40m. 00s. Mean time at Greenwich, in latitude 32° S., longitude 135° W., find the names (from the *Nautical Almanac*) of the stars of the first magnitude or brighter that will be within 1½ hours East of your meridian, above the pole and above the horizon. Required also, approximately, the hour angle, etc. (as above).

STAR TIME AZIMUTH.

To find the true azimuth of a star by means of the " Time Azimuth Tables."

The Tables now supplied at the examinations are the ALT-AZIMUTH TABLES by Percy L. H. Davis. Their use has already been fully explained in the Sun Time Azimuth.

The true azimuth of a star or any other object whose declination does not exceed 24° may be taken out in exactly the same way **by using the hour angle of the object** instead of the Apparent time at ship.

THE WORKING IS AS FOLLOWS :—

Find the R.A.M.

Underneath the R.A.M. write down the star's R.A. The difference between them is the **star's hour angle.**

If the star's R.A. is greater than the R.A.M., **the hour angle is E.**

If the star's R.A. is less than the R.A.M., **the hour angle is W.**

Also write down the star's declination.

To find the star's true azimuth from the tables.

Latitude and declination **same names** are given in the first part of the tables, **contrary names** in the latter part of the tables.

Turn up the page in the tables which corresponds to your latitude and declination, and using the star's hour angle, copy down the true azimuth. Be careful to always take out the azimuth which is in its proper declination column and abreast of the hour angle in the right-hand margin of the page under $\left\{\begin{matrix}\text{Appt. time P.M.}\\ \text{Star's H.A.}\end{matrix}\right\}$

The azimuth which you take out is corrected for odd minutes of latitude, declination, and time (if any), in the same way as in the sun time azimuths, and as shown in the following worked examples.

The true azimuth is always named **the same name as the latitude** and **the same name as the hour angle.**

The error and deviation of the compass are also found in exactly the same way as in azimuths of the sun.

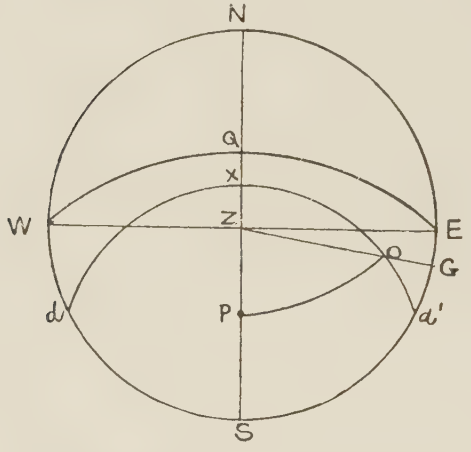
FIGURE FOR STAR TIME AZIMUTH.

This figure is constructed in exactly the same way as that for the Sun's "Time Azimuth."

The fact that a star is being used instead of the sun will not alter the figure in any way. It will, however, be necessary to find the star's hour angle before the figure can be drawn.

FIGURE FOR WORKED EXAMPLE I.

Given Lat. 41½° S.
Decl. 18° S.
Hour angle must be found
5h. 34m. E.



EXPLANATION OF THE FIGURE.

(To be written at the examination.)

The circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial.
P the pole.
d' O X d the parallel of declination.
O the object at the time of observation.
Z O G a vertical circle drawn through the object.
O G the altitude (not used in this problem).
Z O the zenith distance (also not used).
Z Q the latitude, *Q X* the declination.
P Z the co-lat.
P O an hour circle drawn through the object.
Z P O the hour angle.
S Z O the true azimuth.

Worked Examples I.

On 7th August, 1929, in latitude 41° 30′ S., longitude 18° 45′ E., a chronometer which was 03m. 50s. slow on Mean time at Greenwich indicated 02h. 26m. 10s. At the same time the star *β Can. Maj.* (Mirzam) bore S. 60° E. by compass. Required the star's true azimuth and the error of the compass, using the "Time Azimuth Tables," also, assuming the variation to be 31° W., find the deviation for the direction of the ship's head.

Longitude E. 18° 45′

4

6,0) 7,5 0

1h. 15m. 0s.

	d.	h.	m.	s.
Time by chrontr., .	7	02	26	10
Slow, . . . +			03	50
G.M.T., . .	7	02	30	00
Long. E., . +		1	15	0
S.M.T., . . .	7	03	45	00

Star's decl., 17° 55′ S.

	d.	h.	h.	m.	s.
R. 7	02	. .	21	00	26·6
Corr. 30m., .		. +			4·9
R. corrected, .		.	21	00	31·5
S.M.T., . .		. +	03	45	00
R.A.M., .		.	00	45	31·5
Star's R.A., .		.	06	19	34
Hour angle, .		.	5	34	02·5 E.

To take the azimuth from the tables.

Lat. 41° S., ...Decl. 17° S.,.....Hour angle 5h. 28m. gives . . . 82·0°
Corr. for 30′ of latitude, . . + ·15

82·15

Lat. 41° gives 82·0°
Lat. 42° gives 82·3

·3
30
6,0) 9·0
·15

Corr. for 55′ of declination. . . — ·73

81·42

Corr. for 6 mins. of hour angle, . — ·98

80·4

Hour angle 5h. 28m. gives 82·0°
Hour angle 5h. 36m. gives 80·7

1·3
6
8) 7·8
·98

Decl. 17° gives 82·0°
Decl. 18° gives 81·2

·8
55
6,0) 4,4·0
·73

True az., . S. 80·4° E.
Obs. az.. . . S. 60·0 E.

Error, . . 20·4 W.
Variation, . 31·0 W.

Deviation, . 10·6 E.

The true azimuth is first taken out from the tables for the given degrees of the latitude, the degrees of the star's declination (the odd minutes being corrected for afterwards), and the next lesser hour angle.

The correction for the odd 30′ of latitude is found by using the degrees of latitude given in the question and the next greater latitude, keeping to the same declination and hour angle.

The correction for the odd 55′ of declination is found by using the degrees of the given star's declination and the next greater declination, keeping to the same latitude and hour angle.

The correction for the odd 6 minutes of time is found by using the hour angles in the tables which are next less and next greater than the hour angle we have worked out, and keeping to the same latitude and declination.

Worked Example II.

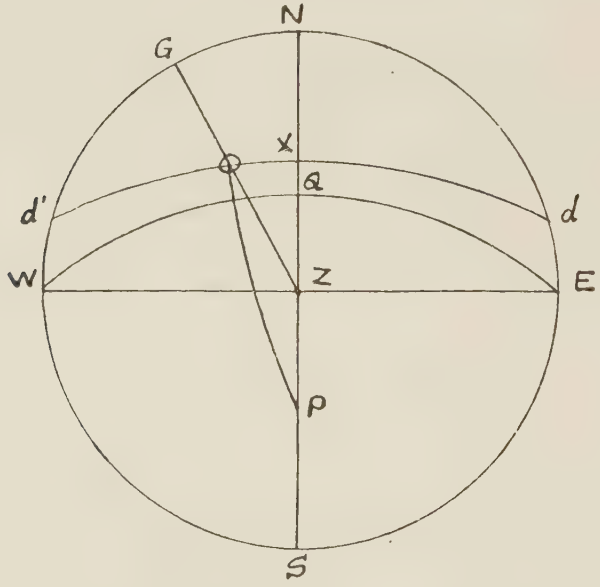
On 19th June, 1929, at 01h. 20m. Apparent time at ship in latitude 41° 30′ S., longitude 131° E., the star *α Ophiuchi* bore by compass N. 34° W. Required the star's true azimuth from the "Time Azimuth Tables," also the error of the compass; and supposing the variation to be 2° E., find the deviation for the direction of the ship's head at the time.

FIGURE FOR WORKED EXAMPLE II.

This figure is constructed in exactly the same way as that for the Sun's "Time Azimuth."

The fact that a star is being used instead of the sun will not alter the figure in any way. It will, however, be necessary to find the star's hour angle before the figure can be drawn.

Given Lat. 41½° S.
Decl. 12½ N.
Hour angle (must be found)
= 1h. 35m. W.



EXPLANATION OF THE FIGURE.

(To be written at the examination.)

The circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial. *P* the pole.
d′ O X d the parallel of declination.
O the object at the time of observation.
Z O G a vertical circle drawn through the object.
O G the altitude (not used in this problem).
Z O the zenith distance (also not used).
Z Q the latitude, *Q X* the declination.
P Z the co-lat.
P O an hour circle drawn through the object.
Z P O the hour angle. *S Z O* the true azimuth.

Worked Example II.

Long. E.
131°
4
60) 524
8h. 44m.

	d.	h.	m.	s.
S.A.T., . .	19	01	20	00
Long. E., . —		8	44	0
G.A.T., . .	18	16	36	00

	h.	m.	s.
H.A.T.S., . .	13	20	00
E., . . .	—11	59	08
S.M.T., . .	01	20	52
R., . .	+17	45	43
R.A.M., . .	19	06	35
Star's R.A., . .	17	31	40
Hour angle, . .	1	34	55 W.

	h.	m.	s.
E. 18d. 16h., ...	11	59	07·8
Corr. 36m., ... —			·3
E. corrected, ...	11	59	07·5

	h.	m.	s.
R. 18d. 16h., ...	17	45	36·7
Corr. 36m., . . . +			5·9
R. corrected, ...	17	45	42·6

Lat., . . 41° 30′ S.
Star's Decl., . 12° 37′ N.
H. angle, . 1h. 35m. W.

Lat. 41° 0′ S., ...Decl. 12° 0′ N. .....

Lat. 41° = 154·0° Decl. 12° = 154·0°
Lat. 42° = 154·3 Decl. 13° = 154·4

·3 ·4
30 37
6,0)9·0(·15 6,0)14·8(·25
60 120
300 280
300

H.A. 1h. 28m. = 154·0°
H.A. 1h. 36m. = 151·8
2·2
7
8)15·4
— 1·9

	Azimuth.
H.A. 1h. 28m. gives . . .	154·0°
Lat. corr., ... +	·15
	154·15
Dec. corr., ... +	·25
	154·4
H.A. corr., ... = —	1·9
	152·5

True az., . . .	S.	152°	30′ W.
		180	0
T. az., . . .	N.	27	30 W.
Obs. az., . . .	N.	34	0 W.
Comp. error, . .		6	30 E.
Variation, . . .		2	0 E.
Deviation, . . .		4	30 E.

The true azimuth is first taken from the tables for the given degrees of latitude and declination (the odd minutes are dealt with afterwards), and the next lesser hour angle.

The correction for the odd 30′ of latitude is found by using the degrees of the latitude given in the question and the next greater latitude, keeping to the same declination and hour angle.

The correction for the odd 37′ of declination is found by using the degrees of the given star's declination and the next greater declination, keeping to the same latitude and hour angle.

The correction for the odd 7 minutes of hour angle is found by using the hour angles in the tables which are next less and next greater than the hour angle we have worked out, and keeping to the same latitude and declination.

Examples for Exercise V.

(1) On 11th January, 1929, at 01h. 14m. Apparent time at ship in latitude 32° 56′ S., longitude 76° 40′ E., the star *α Tauri* (Aldebaran) bore N. 51° W. by the standard compass. Required the true azimuth from the "Time Azimuth Tables," also the error of the compass, and supposing the variation to be 16° W., find the deviation for the direction of the ship's head at that time.

(2) On 19th March, 1929, at 19h. 10m. Apparent time at ship in latitude 41° 8′ N., longitude 163° 20′ E., the star *α Leonis* (Regulus) bore by compass S. 87° E. Required the star's true azimuth and the error of the compass, using the "Time Azimuth Tables," also find the deviation, assuming the variation to be 4° 10′ E.

(3) On 26th September, 1929, at 23h. 46m. Mean time at ship in latitude 32° 50′ N., longitude 22° W., the star *γ Orionis* (Bellatrix) was observed to bear S. 89° E. by the standard compass. Required the true azimuth, using the "Time Azimuth Tables," also the error of the compass, and supposing the variation to be 20° W., find the deviation.

(4) On 4th August, 1929, at 03h. 10m. Mean time at ship in latitude 32° 30′ N., longitude 28° 30′ E., the observed azimuth of the star *α Tauri* (Aldebaran) was N. 84° E. Required the true azimuth from the "Time Azimuth Tables," also the error and deviation of the Compass. Variation 5° W.

(5) On 20th May, 1929, in latitude 41° 8′ S., longitude 42° 30′ W., time by a chronometer (21st May) 02h. 16m. 42s., which was 6m. 42s. fast for Mean time at Greenwich, the star *α Aquilæ* (Altair) bore by compass East. Required the true azimuth and error of the compass by the Time Azimuth Tables, there being no variation in that locality, state the amount and name of the deviation.

(6) On 15th April, 1929, in latitude 52° 20′ N., longitude 3° E., time by a chronometer 21h. 43m. 15s., which was 2m. 00s. slow for Mean time at Greenwich, the star *α Canis Minoris* (Procyon) bore by compass S. 65° W. Required the true azimuth and error of the compass by the Time Azimuth Tables, and supposing the variation to be 12° W., required the deviation of the compass for the direction of the ship's head.

TO FIND THE LATITUDE FROM AN EX-MERIDIAN ALTITUDE OF THE SUN OR A STAR,

OR,

"REDUCTION TO THE MERIDIAN."

In this problem an altitude of the sun or of a star when near the meridian is given, together with the latitude by account, longitude of the ship, and the time of observation.

Using the co-lat., polar distance, and observed zenith distance as the three sides, together with the hour angle, a spherical triangle is formed from which the object's meridian zenith distance is calculated. The object's declination applied to it gives the latitude of the place of observation. The latitude of the ship at noon is found by applying to it the difference of latitude made good between the time of observation and noon. A run is not given with a star observation.

Note that in the case of the sun, the true sun's hour angle or time from apparent noon is always required for working out this problem.

If the time by chronometer with its error on Mean time at Greenwich is given arrange the time as follows :—

Time by chronometer,.....
Error on G.M.T., ...

G.M.T., ... { Correct E. and declination from the *Nautical Almanac.*
Long. in time, E. +, W. —, ...

S.M.T., ...
E., + ...

H.A.T.S., ... { If over 23 hrs. subt. from 24 hrs., to get Easterly hour angle or time from noon = P.

If the Error is given on Apparent time at Ship with the Difference of Long. made since this error was determined arrange it as under :—

Time by watch or chronometer, ...
Error on Apparent time at ship, ...

Approximate Apparent time at ship, ...
D. Long. since error was found (E +) (W —),.....

S.A.T., ... { S.A.T. ~ 12 hrs. = time from noon = P.
Longitude in time (E —) (W +), ...

G.A.T., ... { Correct E.

It would be good enough to correct the declination for the G.A.T., but it is better in principle to use the G.M.T. (found below).

H.A.T.S., ...
E. —, ...

S.M.T., ...
Long. E. —, W. +, ...

G.M.T., ... { Correct Sun's declination.

To find the value of P used in the formula shown below.

The value of P is equal to the time from apparent noon in all cases of the sun.

If the H.A.T.S. is less than 1 hour it represents the time from Apparent noon and is the value of P.

If the H.A.T.S. is more than 23 hours, subtract it from 24 hours to get the Easterly hour angle or time from Apparent noon, which is the value of P.

All ex-meridians of the sun are taken within, say, an hour from noon.

The H.A.T.S. must, therefore, always work out to less than 1 hour or more then 23 hours. The S.A.T. must always be within an hour from noon.

Next copy down the observed altitude and correct it in the same way that you did in meridian altitude of the sun, to get the **true altitude.**

Subtract the true altitude from 90° to get the zenith distance (call this the observed zenith distance).

The meridian zenith distance is then calculated by means of the haversine formula as shown below.

Given in the spherical triangle $P\,Z\,X$ the sides $P\,Z$ (the approx. co-lat.), $P\,X$ (the polar distance), $Z\,X$ (p) (the observed zen. dist.), and angle P (the hour angle).

Required to find $P\,Z \sim P\,X$ (the meridian zenith distance).

Formula.—Hav. p—(hav. P sin $P\,Z$ sin $P\,X$)=hav. ($P\,Z \sim P\,X$)

The working is as follows :—

Add together the log haversine P, the log sin $P\,Z$, and the log sin $P\,X$.

The sum of these is a log haversine which gives us the corresponding **natural** haversine found abreast of it in the haversine table.

Write this natural haversine down underneath the log haversine (drawing a line between them), as shown in the worked examples.

The difference between this natural haversine and the natural haversine of the observed zenith distance (which must be written down underneath it) **is the natural haversine of the meridian zenith distance.**

Write down the meridian zenith distance and name it the opposite name to the bearing of the object.

Underneath it copy down the correct declination, and if they have the same names add them together, but if different names subtract one from the other. The result is the latitude, which is always named the same as the greater one of the two.

Remember that the latitude found by reduction to the meridian is the latitude of the place of observation. This is generally called the " latitude at sights," and should always be within a few miles of the latitude by account.

The question often asks for the **latitude at noon**, the course and distance in the interval between sights and noon being given.

To find it you must take out from the traverse table the difference of latitude corresponding to this course and distance, and apply it to the latitude at sights.

If the sight was taken **after** noon, the name of the diff. of lat. must be reversed, but if taken **before** noon it must not be changed.

Then, if the latitude at sights and the diff. of lat. have the **same names add them together,** but if they have **different names subtract one from the other. The result is the latitude at noon.**

Worked Example I.

(Error on Mean time at Greenwich given.)

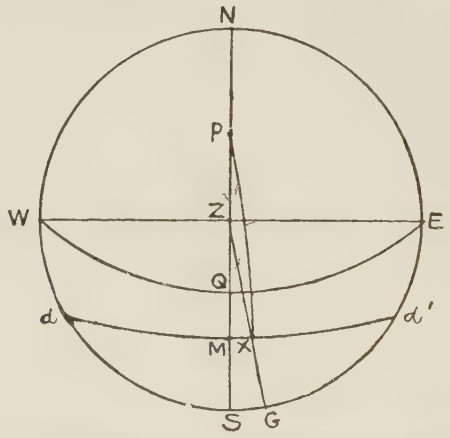
On 11th January, 1929, in latitude by account 42° 18′ N., longitude 33° 26′ W., the observed altitude of the sun's L.L. near the meridian was 25° 18·8′ South of the observer, height of eye 34 feet, time by a chronometer 14h. 04m. 17s., which was 11m. 44s. fast of Mean time at Greenwich. Required the latitude of the ship at the time of taking the observation, also required the latitude at noon, the ship having run 067° 6 miles between the time of taking the observation and noon.

FIGURE FOR REDUCTION TO THE MERIDIAN.

The figure for the ex-meridian may be drawn in exactly the same way as for the time azimuth.

It is, however, not necessary to place the object with strict accuracy by means of the complement of its hour angle. If you put it near the meridian on its proper side, that will be quite good enough.

FIGURE FOR WORKED EXAMPLE I.



Given Lat. 42° N.
Decl. 22 S.
And indirectly, time from noon 29m. 11s.

The circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

N Z S the observer's meridian.
Z the observer's zenith.
W Z E the prime vertical.
W Q E the equinoctial.
P the pole.
d M X d′ the parallel of declination.
X the object at time of observation.
Z P X its hour angle (time from noon).
G X its altitude at time of observation.
S M its meridian altitude.
Z X its zenith distance at time of observation.
Z M its meridian zenith distance.

Worked Example I.

		d.	h.	m.	s.
Long. W.	Time by chrontr.,	11	14	04	17
33° 26′	Fast, . .	—		11	44
4					
	G.M.T., . .	11	13	52	33
6,0) 13,3 44′	Long. W., .	—	2	13	44
2h. 13m. 44s.	S.M.T., . .	11	11	38	49
	E., . .	+	11	52	00
	H.A.T.S., .		23	30	49
			24	00	00
	Sun's Easterly H.A.,		0	29	11 = *P*.

	h.	m.	s.
E. 11d. 14h., ...	11	52	00·4
(no correction)			

	°	′	
Decl. 11d. 14h., . . .	21	49·6	S.
(no correction)			

	°	′	
Obs. alt., . . .	25	18·8	S.
Dip, ... —		5·7	
	25	13·1	
Ref., . . —		2·0	
	25	11·1	
Plx., . . . +		·1	
S. dia., . . +		16·3	
True alt., . . .	25	27·5	
	90	0	
Zen. dist. (observed), .	64	32·5	

	°	′	
Latitude by account, . .	42	18	N.
	90	0	
Approx. co-lat., . . .	47	42	= *P Z*

Given in spherical triangle *P Z X* the sides *P Z* (the approx. co-lat.), *P X* (the polar distance), and angle *P* (the hour angle), also *Z X* (*p*) (the observed zenith distance).

Required to find *P Z* ~ *P X* (the meridian zenith distance).

Formula —

$$\text{Hav. } p - (\text{hav. } P \sin PZ \sin PX) = \text{hav. } (PZ \sim PX).$$

P (hour angle) . . .	= 29m. 11s.	log hav., . .	7·60726
P Z (approx. co-lat.) . .	= 47° 42′	log sin, . .	9·86902
P X (polar dist.) . . .	= 111° 49·6′	log sin, . .	9·96769
		log hav., . .	7·44397 *
		nat. hav., . .	0·00278
p (obs. zen. dist.) . .	= 64° 32·5′	nat. hav., . .	0·28507
		nat. hav., . .	0·28229

	°	′	
Mer. zen. dist., . . .	64	11·25	N.
Corr. decl., ...	21	49·6	S.
Lat. at sights, . . .	42	21·65	N.
D. lat..		2·3	N.
Lat. at noon, . . .	42	23·95	N.

* The log haversine is here turned into the natural haversine.
The natural haversine is found abreast of the log haversine in the haversine table.

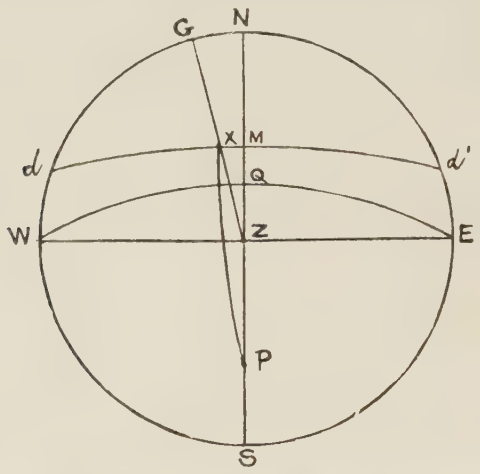
Worked Example II.

(Error on Apparent time at ship given.)

On 2nd August, 1929, in latitude by account 28° 14′ S., longitude 81° 15′ E., the observed altitude of the sun's L.L. near the meridian was 43° 19·6′ North of the observer, index error 1·2′ to add, height of eye 29 feet, time by a watch 06h. 42m. 44s., which had been found to be slow of Apparent time at ship 5h. 43m. 47s., but the ship had made 16′ difference of longitude to the Westward since the determination of the error on Apparent time at ship.

Required the latitude of the ship at the time of taking the observation ; also required the latitude at noon, the ship having run 294° 5 miles between noon and the time of taking the observation.

FIGURE FOR WORKED EXAMPLE II.



Given Lat. 28° S.
Decl. 18° N.
And indirectly, time from noon, 25m. 27s.

The circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial.
P the pole.
d X M d′ the parallel of declination.
X the object at the time of observation.
M the point where it crossed the meridian.
Z P X its hour angle (time from noon).
G X its altitude at time of observation.
N M its meridian altitude.
Z X its zenith distance at time of observation.
Z M its meridian zenith distance.
Q M its declination.
Z Q the latitude.

Worked Example II.

Long. E. 81° 15′ 4

6,0) 32,5 0

5h. 25m. 0s.

	d.	h.	m.	s.
Time by chrontr., .	2	06	42	44
Slow, . . . +		5	43	47
Appx. time ship,* .	2	12	26	31
D. long. W., . . —			1	4
S.A.T., . . .	2	12	25	27
Long. E., . . —		5	25	0
G.A.T., . . .	2	07	00	27

D. Long. 16′ W. 4

6,0) 6,4

1m. 4s.

	h.	m.	s.
H.A.T.S., . . .	0	25	27
E., ...	11	53	51
S.M.T., . .	2 12	31	36
Long. E., . . —		5	25	0
G.M.T., . .	2	07	06	36

E.

d.	h.	h.	m.	s.	
2	6 =	11	53	50·9	Var. 2 hrs. = ·4s.
Corr. 1 hr. +				·2	Var. 1 hr. = ·2s.
E.	=	11	53	51·1	

Declination.

d.	h.	°	′		
2	6 =	17	53·9	N.	Var. 2 hrs. = 1·3′
Cor. 1·1 hrs.,		—	·7		Var. 1 hr. = ·65′
Decl.,		17	53·2	N.	1·1
					65
					65
					·715

	°	′	
Latitude by account, . .	28	14	S.
	90	0	
Approx. co-lat., . . .	61	46	= *P Z*

Given in spherical triangle *P Z X* the sides *P Z* (the approx. co-lat.), *P X* (the polar distance), *Z X* (*p*) (the observed zen. dist.), and angle *P* (the hour angle).

Required to find *P Z* ~ *P X* (the meridian zenith distance).

Formula.—

Hav. *p* − (hav. *P* sin *P Z* sin *P X*) = hav. (*P Z* ~ *P X*).

P (hour angle)	= 25m. 27s.	log hav.	7·48850
P Z (approx. co-lat.)	= 61° 46′	log sin	9·94499
P X (polar dist.)	= 107° 53· 2′	log sin	9·97849
		log hav.	7·41198
		nat. hav.	0·00258
p (obs. zen. dist.)	= 46° 29·6′	nat. hav.	0·15578
		nat. hav.	0·15320

	°	′	
Mer. zen. dist., . .	46	5·1	S.
Corr. decl., . .	17	53· 2	N.
Lat. at sights, . .	28	11· 9	S.
D. lat., . . .		2·0	S.
Lat. at noon., . .	28	13·9	S.

	°	′	
Obs. alt., ...	43	19·6	N.
Ind. error, . . . +		1·2	
	43	20·8	
Dip, ... —		5·3	
	43	15·5	
Ref., ... —		1·0	
	43	14·5	
Plx., ... +		·1	
S. dia., ... +		15·8	
True alt., . . .	43	30·4	
	90	0	
Zen. dist. (observed), . .	46	29·6	

* It will be noted that the question gives the chronometer time with an **error on Apparent time at ship** which had been found during the morning, and that it states how much difference of longitude has been made **since the error was determined.**

When we have applied the given error to the chronometer time we have only obtained the **approximate** time at ship, because that error was found probably some hours ago. To bring it up to the time of the present observation the difference of longitude made since the error was found must be turned into time and applied to it. The result will be the **real** Apparent time at ship.

As the ship is running to the Westward she is putting her clocks **back**, the correction of 1m. 4s. is, therefore, subtracted.

If she had been running to the Eastward, she would have been putting her clocks **forward**, in which case the correction for the difference of longitude would have been added.

Examples for Exercise VI.

(Mean time at Greenwich given.)

(1) On 7th January, 1929, in latitude by account 56° 18′ S., longitude 67° 22′ W., the observed altitude of the sun's L.L. near the meridian was 55° 54′ North of the observer, height of eye 25 feet, time by a chronometer 16h. 16m. 35s., which was 9m. 14s. slow of Mean time at Greenwich. Required the latitude of the ship at the time of taking the observation ; also required the latitude at noon, the ship having run 286°, 2 miles between the time of taking the observation and noon.

(2) On 15th May, 1929, in latitude by account 48° 29′ N., longitude 128° 31′ W., the observed altitude of the sun's L.L. near the meridian was 59° 53′ South of the observer, index error 3′ to subtract, height of eye 24 feet, time by a chronometer 20h. 57m. 16s., which was 5m. 16s. fast of Mean time at Greenwich. Required the latitude of the ship at the time of taking the observation, also at noon, the ship having run 034°, 5 miles between noon and the time of taking the observation.

(3) On 15th June, 1929, in latitude by account 28° 54′ S., longitude 178° 56′ E., the observed altitude of the sun's L.L. near the meridian was 37° 31′ North of the observer, height of eye 21 feet, time by a chronometer 00h. 00m. 12s., which was 10m. 20s. fast of Mean time at Greenwich. Required the latitude of the ship at the time of observation, also at noon, the ship having run 090°, 3 miles between the time of taking the observation and noon.

(4) On 26th December, 1929, in latitude by account 46° 37′ N., longitude 179° 30′ E., the observed altitude of the sun's upper limb near the meridian was 19° 56′ South of the observer, index error 2′ 30″ to subtract, height of eye 20 feet, time by a chronometer (25th December) 23h. 43m. 10s., which was 16m. 40s. fast of Mean time at Greenwich. Required the latitude of the ship at the time of observation, also at noon, the ship having run 180°, 7 miles between the time of observation and noon.

Examples for Exercise VII.

(Apparent time at ship given.)

(5) On 21st May, 1929, in latitude by account 34° 51′ S., longitude 163° 25′ E., the observed altitude of the sun's L.L. near the meridian was 34° 45′ North of the observer, index error 3′ to subtract, height of eye 22 feet, time by a watch 00h. 42m. 34s., which had been found to be slow of Apparent time at ship 10h. 50m. 04s., but the ship had made 27′ difference of longitude to the Eastward since the determination of the error on Apparent time at ship.

Required the latitude of the ship at the time of taking the observation; also required the latitude at noon, the ship having run 108°, 6 miles between the time of taking the observation and noon.

(6) On 24th June, 1929, in latitude by account 46° 1′ N., longitude 35° 12′ E., the observed altitude of the sun's lower limb near the meridian was 66° 44·5′ bearing South of observer, index error 3′ 30″ to add, height of eye 30 feet. A chronometer showed 09h. 51m. 08s., which had been found by morning sights to be 2h. 32m. 32s. slow on Apparent time at ship, the ship having made 13′ difference of longitude to the Westward since this error was determined.

Required the latitude at the time of observation, and if the ship made 252°, 4 miles between noon and sights, find the latitude at noon.

(7) On 24th December, 1929, in latitude by account 25° 20′ N., longitude 73° 26′ W., the observed altitude of the sun's lower limb near the meridian was 40° 6·5′, the observer being to the Northward of the sun, index error 3′ 30″ to add, height of eye 38 feet. Time by watch 16h. 36m. 48s., which had been found by morning sights to be 5h. 12m. 51s. fast on Apparent time at ship. the ship having made 29′ difference of longitude to the Westward since the above error was determined.

Required the latitude by reduction to the meridian.

REDUCTION TO THE MERIDIAN (STAR).

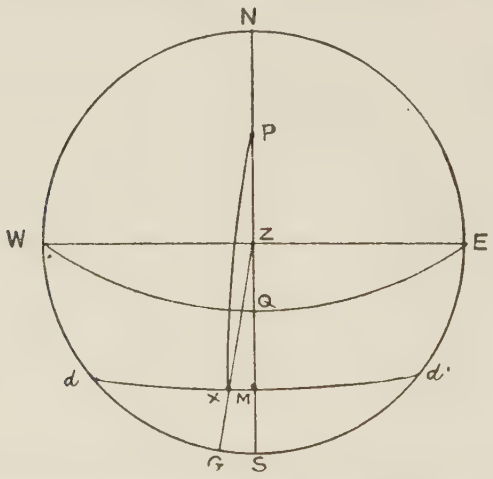
The first thing to do is to find the R.A.M. and the star's hour angle.

Then carry on in the same way as in the ex-meridian of the sun, but using the star's hour angle instead of the hour angle of the sun. The sun's hour angle is the time from Apparent noon. The star's hour angle is the time which elapses between the time of the observation and the time when the star is on the meridian. In other words, it is the difference between the Right ascension of the observer's meridian and the Right ascension of the star.

Worked Example I.

On 19th June, 1929, in latitude by account 32° 59′ N., longitude 138° 30′ W., the observed altitude of the star *α Piscis Australis* (Fomalhaut) near the meridian was 26° 49·2′ South of the observer, height of eye 36 feet, time by a chronometer 14h. 53m. 57s., which was 9m. 42s. fast of Mean time at Greenwich. Required the latitude of the ship by "Reduction to the meridian."

FIGURE FOR WORKED EXAMPLE I.



Given Lat. 33° N.
Decl. 30° S.
To be found Hour Angle 0h. 26m. W.

The circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial.
P the pole.
d X M d′ the parallel of declination.
X the object at the time of observation.
M the point where it crossed the meridian.
Z P X its hour angle.
G X its altitude, and *Z X* its zenith distance at the time of observation.
S M its meridian altitude, and *Z M* its meridian zenith distance.

STAR REDUCTION.

Worked Example I.

Long. W.
138° 30′
4
60) 554 0
9h. 14m. 0s.

	d.	h.	m.	s.
Time by chronometer,	19	14	53	57
Fast, ... —			9	42
G.M.T., . . .	19	14	44	15
Long. W., . . —		9	14	0
S.M.T., . . .	19	5	30	15

	°	′	
Lat. by account, .	32	59	N.
	90	00	
Approx, co-lat., .	57	01	= $P Z$

R.	h.	m.	s.
d. h.			
19 14	17	49	13·6
Corr. 44m., . . . +			7·2
R. corrected, . . .	17	49	20·8
S.M.T., ...	05	30	15
R.A.M., ...	23	19	35·8
Star's R.A., . . .	22	53	45
Hour angle, . . .	0	25	51 W.

	°	′	
Star's decl., . . .	29	59·7	S.
	90	00	
Polar dist., . . .	119	59·7	= $P X$

Given in spherical triangle $P Z X$ the sides $P Z$ (the approx. co-lat.), $P X$ (the polar distance), $Z X$ (p) (the observed zen. dist.) and angle P (the hour angle).

Required to find $P Z \sim P X$ (the meridian zenith distance).

Formula.—

$$\text{Hav. } p - (\text{hav. } P \sin P Z \sin P X) = \text{hav. } (P Z \sim P X)$$

P (hour angle) = 25m. 51s.
$P Z$ (approx. co-lat.) = 57° 01′
$P X$ (polar dist.) = 119° 59·7′

log hav.	7·50203
log sin	9·92367
log sin	9·93755
log hav.	7·36325
nat. hav.	0·00231
nat. hav.	0·27542
nat. hav.	0·27311

(p) = $Z X$ (obs. zen. dist.) = 63° 18·6′

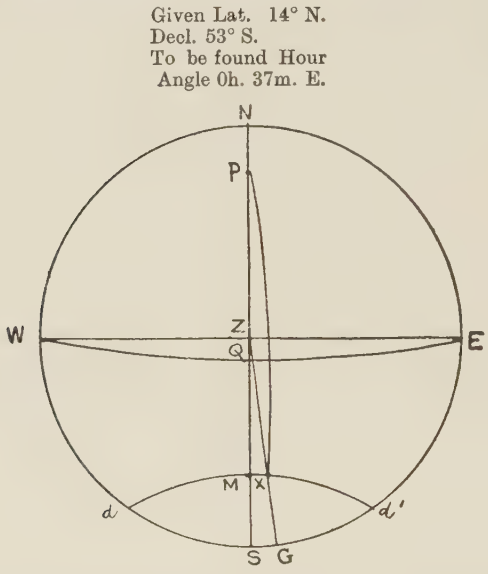
	°	′	
Mer. zen. dist., . .	63	0·8	N.
Declination, . .	29	59·7	S.
Latitude, . . .	33	01·1	N.

	°	′	
Obs. alt., ...	26	49·2	S.
Dip., ... —		5·9	
	26	43·3	
Ref., ... —		1·9	
True alt., ...	26	41·4	
	90	0	
Zen. dist. (observed), . .	63	18·6	N.

Worked Example II.

On 27th December, 1929, in latitude by account 13° 50′ N., longitude 86° 36′ E., the observed altitude of the star *α Argus* (Canopus) near the meridian was 23° 04′ South of the observer, height of eye 21 feet, time by a watch was 17h. 39m. 20s., which had been found to be 5h. 41m. 10s. slow of Apparent time at ship, but the ship had made 13′ difference of longitude to the Eastward since the determination of the error on Apparent time at ship. Required the latitude of the ship by "Reduction to the meridian."

FIGURE FOR WORKED EXAMPLE II.



The circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial.
P the pole.
d M X d′ the parallel of declination.
X the object at the time of observation.
M the point where it will cross the meridian.
Z P X its hour angle.
G X its altitude, and *Z X* its zenith distance at the time of observation.
S M its meridian altitude, and *Z M* its meridian zenith distance.
Q M the declination.
Z Q the latitude.

Worked Example II.

Long. E.
86° 36′
4

6,0) 34,6 24

5h. 46m. 24s.

	d.	h.	m.	s.
Time by chronometer,	27	17	39	20
Slow, ... +		5	41	10
	27	23	20	30
Run E., . . +				52
S.A.T., . . .	27	23	21	22
Long. E., . . −		5	46	24
G.A.T., . . .	27	17	34	58

E.

d.	h.	h.	m.	s.
27	16	11	58	53·3
Corr. 1·6 h., . . . −				2·0
E. corrected, . . .		11	58	51·3

	h.	m.	s.
H.A.T.S., . .	11	21	22
E., . . . −	11	58	51
S.M.T., . . .	23	22	31
R., . . . +	06	22	51
R.A.M., . .	05	45	22
Star's R.A., . .	06	22	26
Hour angle, . .		37	04 E.

R.

d.	h.	h.	m.	s.
27	16	06	22	35·5
Corr. 1h. 35m., . . . +				15·6
R. corrected, . . .		06	22	51·1

	°	′	
Lat. by acct., .	13	50	N.
	90	00	
Approx. co-lat., .	76	10	= PZ

	°	′	
Star's decl., . . .	52	39·2	S.
	90	00	
Polar dist., . . .	142	39·2	= PX

Given in spherical triangle PZX the sides PZ (the approx. co-lat.), PX (the polar distance), ZX (p) (the observed zen. dist.), and angle P (the hour angle).

Required to find $PZ \sim PX$ (the meridian zenith distance).

Formula.—

$$\text{Hav. } p - (\text{hav. } P \sin PZ \sin PX) = \text{hav. } (PZ \sim PX)$$

P (hour angle) = 37m. 4s.
PZ (approx. co-lat.) = 76° 10′
PX (polar dist.) = 142° 39·2′

log hav.	7·81459
log sin	9·98722
log sin	9·78293
log hav.	7·58474
nat. hav.	0·00384
nat. hav.	0·30499
nat. hav.	0·30115

(p) = ZX (obs. zen. dist.) = 67° 2·7′

	°	′	
Obs. alt., ...	23	4·0	S.
Dip, ... −		4·5	
	22	59·5	
Ref., ... −		2·2	
True alt., . . .	22	57·3	
	90	0	
Zen. dist. (observed), . .	67	2·7	N.

	°	′	
Mer. zen. dist., . .	66	34	N.
Declination, . .	52	39·2	S.
Latitude, . . .	13	54·8	N.

Examples for Exercise VIII.

(1) On 10th January, 1929, in latitude by account 14° 20′ S., longitude 32° 15′ W., the observed altitude of the star *a Crucis* near the meridian was 41° 45′ South of the observer, height of eye 26 feet, time by a chronometer was 07h. 20m. 10s., which was 8m. 6s. slow of Mean time at Greenwich. Required the latitude of the ship by "Reduction to the meridian."

(2) On 9th May, 1929, in latitude by account 48° 34′ N., longitude 158° 36′ E., the observed altitude of the star *a Aquilæ* (Altair) near the meridian was 50° 04′ South of the observer, height of eye 33 feet, time by a chronometer was (8th May) 17h. 56m. 20s., which was correct Mean time at Greenwich. Required the latitude by "Reduction to the meridian."

(3) On 19th March, 1929, in latitude by account 36° 28′ N., longitude 128° 36′ W., the observed altitude of the star *a Scorpii* (Antares) near the meridian was 27° 23′ South of the observer, index error 2′ 30″ to subtract, height of eye 24 feet, time by a chronometer 13h. 33m. 10s., which was 7m. 34s. fast of Mean time at Greenwich. Required the latitude of the ship by Reduction to the meridian.

Examples for Exercise IX.

(4) On 23rd September, 1929, in latitude by account 0° 24′ S., longitude 26° 42′ W., the observed altitude of the star *a Eridani* (Achernar) near the meridian was 32° 50′ South of the observer, index error 3′ 30″ to subtract, height of eye 31 feet, time by a watch was 03h. 46m. 42s., which had been found to be 1h. 54m. 8s. fast of Apparent time at ship, but the ship had made 8′ difference of longitude to the Westward since the determination of the error on Apparent time at ship. Required the latitude.

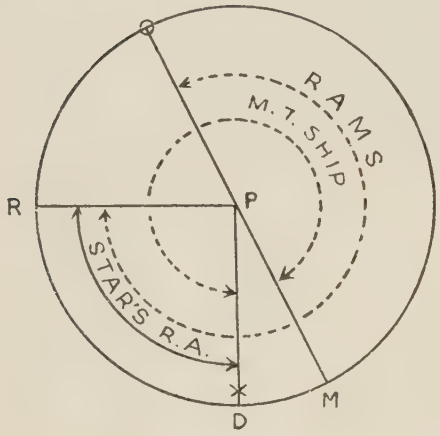
(5) On 28th December, 1929, in latitude by account 36° 43′ N., longitude 132° 15′ W., the observed altitude of the star *a Canis Majoris* (*Sirius*) near the meridian was 36° 41′ South of the observer, height of eye 22 feet, time by a watch (29th December) 08h. 47m. 34s., which had been found to be 8h. 50m. 52s. fast of Apparent time at ship, but the ship had made 15′ difference of longitude to the Westward since this error was determined. Required the latitude by Reduction to the meridian.

TO FIND THE TIME AT WHICH ANY GIVEN STAR WILL BE ON THE OBSERVER'S MERIDIAN.

Candidates must be able to work this problem out either by calculation or inspection (see following pages).

Worked Example I.

On 9th January, 1929, in latitude by account 32° 20′ S., longitude 156° 30′ W., required the approximate Mean time at ship when the star *α Orionis* (Betelguese) will be on the meridian.



The circle represents a stereographic projection of the celestial sphere on the plane of the equinoctial.

P the pole.
P D the observer's meridian.
X the star on the meridian.
R the First point of Aries.
P R the meridian through it.
O the mean sun.
P O the meridian through it.
R D the star's R.A.
R D M O the mean sun's R.A.
Angle *D P M* (clockwise) the M.T. ship.

The Right ascension of a celestial body is its distance, expressed in time, East of the First point of Aries.

As the star's R.A. is about 6 hours, the star is about 6 hours East of the First point of Aries, consequently the First point of Aries must be about 6 hours **West** of the star.

To find the position of the First point of Aries on the equinoctial we must, therefore, measure off an arc of about 90° to the Westward of the meridian of the star (and of the observer), which gives us *R* as the position of the First point of Aries and *P R* the meridian passing through it.

Then arc *R D* or angle *R P D* represents the star's R.A.

To show the position of the mean sun we must use its Right Ascension (R.A.M.S.), which is R + 12 hrs. (reject 24 hrs. when the sum exceeds 24 hrs.).

As *R* is about 7 hrs., the R.A.M.S. is about 19 hrs., so we measure off an arc of about 19 hrs. (285°) East (anticlockwise) of the meridian through the first point of Aries, which gives us *O* as the position of the Mean sun and *P O* the meridian passing through it.

P.M. is the meridian opposite to it, which is the meridian of midnight.

Then arc *R D M* or angle *R P M* represents the value of *R* and arc *R D M O* or angle *R P O* (anticlockwise) represents the R.A.M.S.

The arc *D R O* or angle *D P O* is the Mean sun's Westerly hour angle, which is the time from noon.

By adding 12 hours to the arc *D R O* we obtain the arc *D R O M* or angle *D P M* (clockwise), which is the time from midnight, and consequently the Mean time at ship.

It will be seen from the figure that the midnight meridian, P.M., is about 22½ hours West of the observer's meridian *P X D*. This agrees approximately with the calculated answer, which is 22h. 33m. 44s.

STAR ON THE MERIDIAN.

Worked Example I.

(Mean time at ship required.)

Long. W.
156° 30′
4

6,0)62,6 0

10h. 26m. 0s.

To find the Greenwich Time.

	h.	m.	s.
Star's R.A., . . .	05	51	20
R. 9d. 00h., . .	07	12	10
S.M.T. (approx.), .	9	22	39	10
Long. W., . . .+	10	26	0
G.M.T. (approx.), .	10	09	05	10

R.

d. h.	h.	m.	s.
10 08	07	17	25·5
Corr. 1h. 5m., . . .+			10·7
R. corrected, . . .	07	17	36·2

To find the M.T. Ship.

	h.	m.	s.
Star's R.A., . . .	05	51	20
R., ...—07	17	36
S.M.T., . . .	9	22	33	44

or 10h. 33m. 44s. P.M.

Write down the star's R.A. and underneath it the value of R. taken from *The Nautical Almanac* for 00 hrs. on the day of the question.

Subtract R. from the star's R.A., increased by 24 hrs. if necessary. The remainder is the S.M.T. approximately to which prefix the date of the question.

To the approximate S.M.T. apply the longitude in time, West add, East subtract ; the result is the approximate G.M.T.

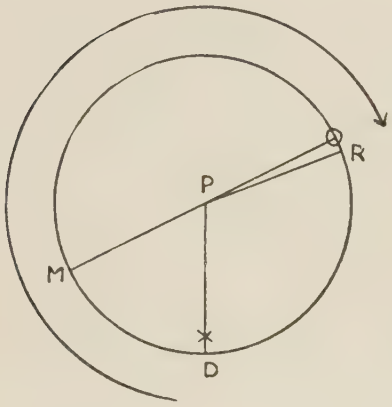
Now take out the value of R. from the *Nautical Almanac* for the 2 hrs. which are next lower than your approximate G.M.T., and correct it in the usual way.

Subtract the correct value of R. from the star's R.A. ; the result is the S.M.T., to which prefix the date of the question.

Worked Example II.

On 24th March, 1929, in latitude by account 43° 20′ S., longitude 175° 30′ E., find the approximate Apparent time at which the star *α Scorpii* (Antares) will be on the meridian.

The circle contains 360°, and as it represents 24 hours, 15° of arc must represent one hour of time. The number of degrees of arc to be allotted to any given amount of time is, therefore, found by multiplying the number of hours by 15.



Right ascension is the distance (expressed in time) which any object is to the **Eastward** of the First point of Aries.

As the star's R.A. is about 16½ hours, the meridian *P R* is drawn about 16½ hours **West** of the meridian of the star (and of the observer); then *R* represents the First point of Aries and *P R* the meridian passing through it. The direction in which to draw *P R* is found by following the line with arrow head for 16½ hours (247½°).

As the value of *R* is about 12h. 03m. the R.A.M.S. is only about 3 minutes, so the meridian passing through the mean sun *O* should be only about 3 minutes or one degree from the meridian passing through the First point of Aries, but it has been increased a little in the figure to make it clearer, and is shown as *P O*.

DESCRIPTION OF THE FIGURE.

(To be written at the examination.)

The circle represents a stereographic projection of the celestial sphere on the plane of the equinoctial.

P the pole.
P D the observer's meridian.
X the star on it.
R the First point of Aries.
O the mean sun.
P O the meridian of mean noon.
P M the meridian of midnight.
R O M D the star's R.A.
R O the R.A.M.S.
D M or angle *D P M* the M.T. ship.

EXPLANATION.

(Not to be written at the examination.)

To find *D P M* the M.T. ship, we first subtract the R.A.M.S. from the star's R.A.—that is, arc *R O* from arc *R O M D*. This leaves the arc *D M O* or angle *D P O* (clockwise), which is the sun's Westerly hour angle.

From this we must subtract 12 hours, in order to measure our time from *P M*, the meridian of midnight. Thus we have *D M O* — *M O* = *D M* or angle *D P M*, which is the M.T. ship.

STAR ON THE MERIDIAN.

Worked Example II.

(Apparent time at ship required.)

Long. E.
175° 30′
4

6,0)70,2 0

11h. 42m. 0s.

To find the G.M.T.

	h.	m.	s.
Star's R.A., . .	16	25	03
R. 24d. 00h., . . —	12	03	55
S.M.T. (approx.), .	24	4	21	08
Long. E., . . —	11	42	00
G.M.T. (approx.), .	23	16	39	08

R.

d. h.	h.	m.	s.
23 16	12	02	36·3
Corr. 39m., . . . +			6·4
R. corrected, . . .	12	02	42·7

E.

d. h.	h.	m.	s.
23 16	11	53	17·6
Corr. 39m. . . . +			·5
E. corrected, . . .	11	53	18·1

Var. 2 hrs. 1·5s.
Var. 1 hr. ·75
·7

·525

	h.	m.	s.
Star's R.A., . .	16	25	03
R., . . . —	12	02	43
S.M.T., . . .	04	22	20
E., . . . +	11	53	18
H.A.T.S., . .	16	15	38
—	12	00	00
S.A.T., . . .	24	04	15	38

or 4h. 15m. 38s. A.M.

Find the approx. G.M.T. in the same way as when Mean time at ship is required. (See above, and Worked Example I.)

Take out R. and E. from the *Nautical Almanac* for the approx. G.M.T., and correct them in the usual way.

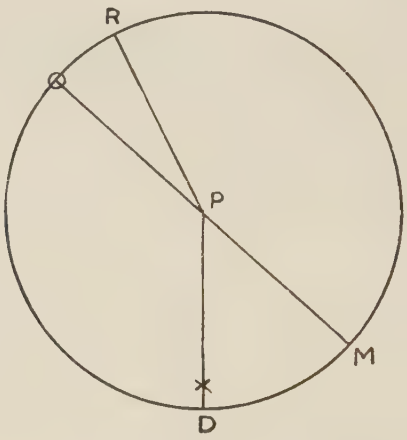
Write down the star's R.A. again, and from it subtract *R*, borrowing 24 hrs. if necessary.

The remainder is the S.M.T., to which add E.

The sum is the H.A.T.S. If under 12 hrs. add 12 hrs. to it ; if over 12 hrs., subtract 12 hrs. from it. The result, with the day of the question prefixed, is the approximate Apparent time at ship required.

Worked Example III.

On 13th April, 1929, at ship, on the equator and the meridian of Greenwich, required the approximate Apparent time at ship when the star *α Leonis* (Regulus) will be on the meridian.



As the star's R.A. is about 10h. 4m., the star is about 10h. 4m. East of the First point of Aries ; it follows, therefore, that the First point of Aries must be about 10h. 4m. **West** of the star.

Measure off 10h. 4m. (151°) to the Westward of the meridian of the star (and of the observer), and draw the line *P R*, which is the meridian passing through the First point of Aries (*R*).

The R.A.M.S. being about 1h. 23m., measure off about 21° from the meridian *P R*, and draw the meridian *P O*, which is the meridian passing through the mean sun (*O*).

DESCRIPTION OF THE FIGURE.

(To be written at the examination.)

The circle represents a stereographic projection of the celestial sphere on the plane of the equinoctial.

P the pole.
P D meridian of observer.
X the star on the meridian.
P R the meridian through the First point of Aries.
P O the meridian through the mean sun.
P M the meridian of midnight.
R O D the star's R.A.
R O the R.A.M.S.
Arc *D O R M* or Angle *D P M* (clockwise) } M.T. ship.

EXPLANATION OF THE FIGURE.

Arc *R O D* (star's R.A.) — arc *R O* (R.A.M.S.) = arc *D O*.

Now arc *D O* = angle *D P O* = sun's Westerly hour angle.

Arc *D O* + 12 hours = arc *D O R M* = angle *D P M* (clockwise), which is the M.T. ship.

STAR ON THE MERIDIAN.

Worked Example III.

(Apparent time at ship required.)

To find the G.M.T.

	h.	m.	s.
Star's R.A.,	10	04	36
R. 13d. 00h., —	13	22	46
S.M.T. (approx.),	13	20	41	50
Long.,	0	0	0
G.M.T. (approx.),	13	20	41	50

R.

d.	h.		h.	m.	s.
13	20		13	26	03·4
Corr. 42m.,		+			6·9
R. corrected,			13	26	10·3

E.

d.	h.		h.	m.	s.
13	20		11	59	27·9
Corr. 42m.,		+			·5
E. corrected,			11	59	28·4

	h.	m.	s.
Star's R.A.,	10	04	36
R., —	13	26	10
S.M.T.,	20	38	26
E., +	11	59	28
H.A.T.S.,	8	37	54
	+12	00	00
S.A.T.,	13	20	37	54

Examples for Exercise X.

Find by calculation the Mean time at ship when the stars mentioned below will be on the meridian on the given dates.

(1) 1929.—January 5th, at ship in latitude 10° 40′ N., longitude 163° 40′ E., star *α Crucis*.

(2) 1929.—March 18th, at ship in latitude 24° 30′ S., longitude 138° 46′ W., star *α Leonis* (Regulus).

(3) 1929.—April 15th, at ship in latitude 20° S., longitude 176° 49′ E., star *α Lyræ* (Vega).

Examples for Exercise XI.

Find by calculation the Apparent time at ship when the stars named below will be on the meridian on the given dates.

(4) 1929.—May 11th, at ship in latitude 38° 40′ S., longitude 17° 45′ W., star *α Triang. Aust.*

(5) 1929.—June 24th, at ship in latitude 38° N., longitude 177° 30′ E., star *α Scorpii* (Antares).

(6) 1929.—August 8th, at ship in latitude 31° 50′ S., longitude 154° 20′ W., star *α Persei* (Mirfak).

STAR ON THE MERIDIAN, BY INSPECTION.

A star reaches the meridian of any place about four minutes earlier on each succeeding day, so that if a star is on the meridian at, say, 02h. 09m. on any day, it will be on the same meridian at about 02h. 05m. on the next day, and at about 02h. 01m. on the next day, and so on.

In **" Norie's Tables "** we are given the approximate Apparent time at which the principal stars are on the meridian of Greenwich on the first and every succeeding fifth day of each month. These times will be approximately correct in any other longitude.

If we want to find the time when a star is on the meridian on any of the dates given in the tables, we copy it down direct from the tables **without making any alteration or correction**

If we require the time of the meridian passage on any intermediate day, we copy down the time of the meridian passage for the next **preceding** day which is given in the tables, and apply a correction to it to bring it up to the required day. This correction (as stated above) is approximately four minutes for every day, but may be obtained more accurately (when it is not exactly four minutes) by proportion, as follows :—

Find the difference between the time of the meridian passage for the next preceding given day and of that for the next following given day, multiply it by the number of days for which the correction is required, and divide the product by five.

The result is a correction to subtract from the time of the meridian passage for the next preceding given day, which gives us the time of the meridian passage **on the day of the question.**

The result obtained by inspection should always be within a few minutes of the result by calculation. They should most nearly agree when the calculated result is in Apparent time, because the time found by inspection is also Apparent time.

The difference caused by the Equation of time may be noticeable when the time found by calculation is Mean time.

STAR ON THE MERIDIAN.

BY INSPECTION.

(1924 Edition of Norie's Tables.)

1929.—January 9th, find the approximate Apparent time when the star "*α Orionis*" (Betelguese) will be on the meridian.

	h.	m.
Mer. pass. preceding day, 6th	= 22	42
,, following day, 11th	= 22	20
Difference in 5 days	=	22
Days from 6th to 9th	=	3
	5)66	
Correction for 3 days	=	13

	h.	m.
Mer. pass. 6th	= 22	42
Corr. 3 days	—	13
Mer. pass. 9th	= 22	29

1929.—March 24th, find approximately the Apparent time at ship at which the star "*α Scorpii*" (Antares) will be on the meridian.

	h.	m.
Mer. pass. preceding day, 21st	= 4	25
,, following day, 26th	= 4	7
Difference in 5 days	=	18
Days from 21st to 24th	=	3
	5)54	
Correction for 3 days	=	11

	h.	m.
Mer. pass. 21st	= 4	25
Corr. 3 days	—	11
Mer. pass. 24th	= 4	14

1929.—February 13th, at ship in latitude 5° S., longitude 20° W., find the approximate Apparent time at ship when the star "*α Argus*" (Canopus) will be on the meridian.

	h.	m.
Mer. pass. preceding day, 11th	= 20	44
,, following day, 16th	= 20	24
Difference in 5 days	=	20
Days from 11th to 13th	=	2
	5)40	
Correction for 2 days	=	8

	h.	m.
Mer. pass. 11th	= 20	44
Corr. 2 days	—	8
Mer. pass. 13th	= 20	36

Examples for Exercise XII.

Find approximately by inspection the Apparent time at ship at which the stars named below will be on the meridian.

(1) 1929.—January 5th, star *α Crucis*.
(2) 1929.—March 18th, star *α Leonis* (Regulus).
(3) 1929.—April 15th, star *α Lyræ* (Vega).
(4) 1929.—May 11th, star *α Triang. Aust.*
(5) 1929.—June 24th, star *α Scorpii* (Antares).
(6) 1929.—August 8th, star *α Persei* (Mirfak).

DOUBLE ALTITUDE (POSITION LINES) PROBLEM. SUMNER'S METHOD.

When an altitude of a heavenly body is observed, the ship's position is at some point in a small circle, the pole of which is vertically under the object, and the spherical radius of which is equal to the object's zenith distance at the time of observation. This circle is called a circle of equal zenith distance, " circle of equal altitude," or " circle of position."

In a Sumner's method two altitudes with a suitable interval between them are taken. From these altitudes we get two circles of position. As the observer's ship is on both circles, it follows that she must be at one of their points of intersection. As the two points will be a long way apart, and the ship's position is known approximately, there can be no trouble in deciding which point it is.

No appreciable error will be caused if small portions of these circles be considered as straight lines and projected on the chart.

The latitude by account at the time of taking the first observation is generally given. By applying to it the difference of latitude corresponding to the run in the interval, the latitude by account at the time of taking the second observation is easily found.

Using these two latitudes, two longitudes are worked out from the altitude obtained at the first observation.

Then with the same two latitudes, two longitudes are worked out from the altitude obtained at the second observation.

The first two longitudes are then laid off on the chart, each one in the latitude used for finding it. A straight line passing through these two points is the " first line of position."

The second two longitudes are then laid off in exactly the same way. A straight line passing through these two points is the " second line of position."

If the ship had remained stationary between the time of taking the two observations, the intersection of these two lines would indicate her position.

If, as is most likely, the ship has moved during the interval, the first line of position must be moved (with the parallel rules) in direction and distance equal to the run. The point of intersection of the two lines will then indicate the ship's position at the time of taking the second observation.

The working is done as follows :—

First Observation.

1. Find the G.M.T., if it is not given.
2. Correct the declination and value of E. for the G.M.T., and find the polar distance.
3. Correct the observed altitude, subtract it from 90°, and obtain the zenith distance.
4. Subtract the latitude at first observation from 90° to obtain the co-latitude. Subtract the latitude at second observation from 90° to obtain the co-latitude.
5. With the polar distance, zenith distance, and first co-latitude, calculate a longitude in the same way as in " Longitude by chronometer," and call it " A."
6. With the same polar distance and zenith distance, but with the second co-latitude, calculate a second longitude and call it " B."

Second Observation.

1. Find the G.M.T. if it is not given.
2. Correct the declination and value of E. for the G.M.T. and find the polar distance.
3. Correct the observed altitude, subtract it from 90°, and obtain the zenith distance.
4. Subtract the latitude at first observation from 90° to obtain the co-latitude. Subtract the latitude at second observation from 90° to obtain the co-latitude.
5. With the polar distance, zenith distance, and first co-latitude, calculate a third longitude and call it " C."
6. With the same polar distance and zenith distance, but with the second co-latitude, calculate a fourth longitude and call it " D."

PROJECTION ON THE CHART.

On the chart given you at the examination it is quite likely that the degrees of longitude will not be numbered. This is in order that you may mark the meridians to correspond with the longitudes which you have calculated.

If the Longitudes are **West,** you must number them *increasing from right to left ;* but number them increasing from *left to right* if the Longitudes are **East.**

Lay off the four positions on the chart, naming them *A*, *B*, *C*, and *D*, being careful to lay off each longitude in the latitude (not the co-latitude) which you used when finding it.

To Find the First Line of Position.—Lay the parallel rules on the two points *A* and *B*, and join them with a straight line. Take off the direction of this line by means of a protractor or Field's parallel rules. It may also be obtained by carefully working your rules until you get their edge on the centre of the compass on the chart. This is the **First line of position.** Write it down, expressing it in degrees.

To Find the Sun's True Bearing.—The sun's true bearing at the first observation is at right angles, or 90° to the **Eastward** of the first line of position if the first observation is a morning one, but 90° to the **Westward** if it was taken in the afternoon.

Likewise, the sun's true bearing at the second observation is 90° to the **Eastward** of the **second** line of position (that is, the *C D* line) if the second observation is a **morning** one, but 90° to the Westward if it was taken in the afternoon.

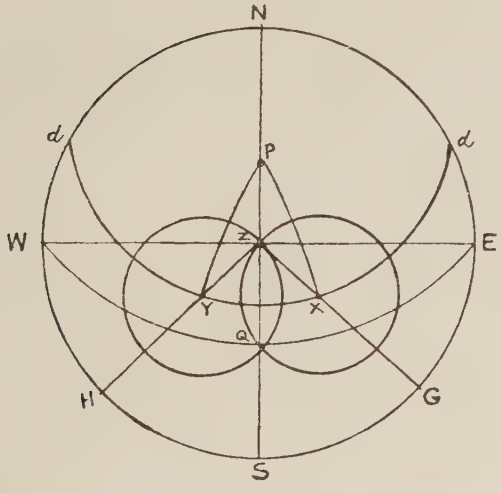
To Find the Ship's Position.—From any point in the *A B* line, lay off the course and distance run between the observations. **From the end of this draw a line parallel to the *A B* line : the point where this cuts the *C D* line is the ship's position at the second observation.** The ship's position at the first observation is not asked for, but it could be found by applying the run **backwards** from her position at the second observation.

NOTES.

Worked Example I.

On 2nd August, 1929, A.M. at ship, in latitude by account 49° 20′ N., longitude by account 49° 50′ W., when a chronometer (corrected) indicated Mean time at Greenwich 13h. 35m. 46s., the observed altitude of the sun's L.L. was 51° 31′, and again P.M. on the same day when the same chronometer (corrected) indicated 16h. 58m. 15s., the observed altitude of the sun's L.L. was 52° 38′, height of the eye at each observation being 24 feet. The ship having made 40 miles on an 060° course during the interval between the observations, required the line of position and the true bearing of the sun when the first altitude was observed ; and the position of the ship when the second altitude was observed.

Given Lat. 49½° N.
Decl. 18 N.
1st obs. alt. 52°
2nd obs. alt. 53°



The circle *N E S W* represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian
W Z E the prime vertical.
W Q E the equinoctial.
Z Q the latitude.
P Z the co-latitude.
P the pole.
d Y X d′ the parallel of declination.
X the object at 1st observation.
G X its altitude.
Z X its zenith distance.
P X its polar distance.
Z P X its hour angle.
Y the object at 2nd observation.
H Y its altitude.
Z Y its zenith distance.
P Y its polar distance.
Z P Y its hour angle.

To Draw the Figure.

The figure for Sumner's method is constructed in the same way as the figure for "longitude by chronometer," but as two observations are taken with a considerable interval between them, two triangles are shown.

The small circles drawn round the object at each observation are "circles of equal altitude," or "circles of equal zenith distance," or "circles of position." They are drawn with the object's zenith distance as radius.

To have obtained these zenith distances, **the observer must have been on the circles.** He could not obtain the same zenith distances anywhere else. Being on both circles, he must be at one of their points of intersection. There is no difficulty in deciding which is the point. It **must** have been *Z*, because the other point is so very far away from the ship's approximate position.

Run, N. 60° E., 40 miles.
D. Lat. 20·0 N.

Lat. 1st obs. 49° 20′ N. . . . . co-lat. 40° 40′ = *P Z*
D. lat., . 20 N.

Lat. 2nd obs. 49° 40′ N. . . . . co-lat. 40 20 = *P Z*

First Observation.

G.M.T. 2d. 13h. 35m. 46s.

To Correct the Declination.

Decl. 2d. 12h.	= 17° 50·0′	N.
Corr. 1·6h.	− 1·0	
Corr. decl.	17° 49·0	N.
	90 0	
Polar dist.	72° 11·0′ = *P X*	

To Find the Value of E.

	h.	m.	s.		s.
E. 2d. 12h.	11	53	51·9	12h.	51·9
Corr. 1·6 h. +			·2	14 h.	52·2
E. corrected,	11	53	52·1	2)	·3
					·15
					1·6
					90
					15
					·240

To Find the Zen. Dist.

		°	′
Obs. alt.,		51	31·0
Dip.	−		4·8
		51	26·2
Ref.	−		·8
		51	25·4
Plx.	+		·1
S. dia.	+		15·8
True alt.,		51	41·3
		90	·0
Zen. dist.,		38	18·7 = *Z X*

Given in triangle *P Z X*, the sides *P Z* (the co-lat.), *P X* (the polar dist.), and *Z X* (*p*) (the zenith distance).
Required to find angle *P* (the hour angle).

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (P Z \sim P X).}{\sin P Z \sin P X}$$

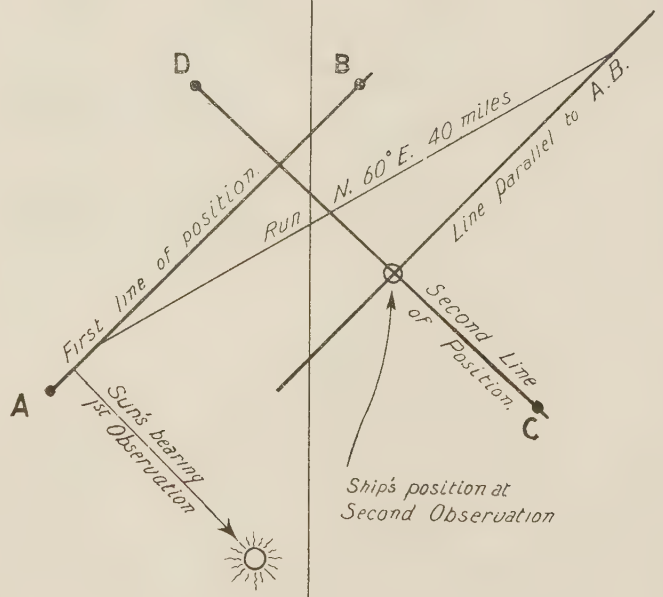
	° ′		
p	= 38 18·7	nat. hav.	0·10768
(*P Z* ~ *P X*)	= 31 31·0	nat. hav.	0·07376
		nat. hav.	0·03392
		log. hav.	8·53042
P Z	= 40° 40·0′	log. cosec	0·18598
P X	= 72 11·0	log. cosec	0·02135
		log hav.	8·73775

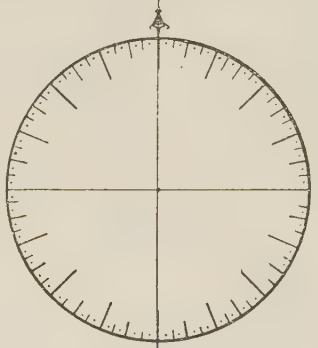
	° ′		
p	= 38 18·7	nat. hav.	0·10768
(*P Z* ~ *P X*)	= 31 51·0	nat. hav.	0·07528
		nat. hav.	0·03240
		log hav.	8·51054
P Z	= 40° 20·0′	log cosec	0·18894
P X	= 72 11·0	log cosec	0·02135
		log hav.	8·72083

	h.	m.	s.
Sun's Ely. H.A., . . .	1	48	10
	24	0	0
H.A.T.S., ...	22	11	50
E., ...	−11	53	52
S.M.T., ...	2	10	17	58
G.M.T., ...	2	13	35	46
		3	17	48
		60		
	4)	197	48	
Longitude (A), ...		49	27	0 W.

	h.	m.	s.
Sun's Ely. H.A., . . .	1	46	3
	24	0	0
H.A.T.S., ...	22	13	57
E., ...	−11	53	52
S.M.T., ...	2	10	20	05
G.M.T., ...	2	13	35	46
		3	15	41
		60		
	4)	195	41	
Longitude (B), ...		48	55	15 W.

Plate I.





[To be inserted between pages 142 and 143.

Second Observation.

G.M.T. 2d. 16h. 58m. 15s.

To Correct the Declination.

	d.	h.	°	′	
Decl.,	2	16	= 17	47·5	N.
Corr. 1 hr.,		—		·6	
Corr. decl.,			17	46·9	N.
			90	0	
Polar dist.,			72	13·1	= *P Y*

To Find the Value of E.

	h.	m.	s.	h.	s.
E. 2d. 16h.,	11	53	52·6	16	52·6
Corr. 1 hr., . +			·1	18	52·9
E. corrected,	11	53	52·7	2)	·3
					·15

To Find the Zenith Dist.

		°	′
Obs. alt.,		52°	38·0′
Dip,	—		4·8
		52°	33·2′
Ref.	—		·7
		52	32·5
Plx.	+		·1
S. dia.	+		15·8
True alt.,		52	48·4
		90	0
Zen. dist.,		37°	11·6′ = *Z Y*

Given in triangle *P Z Y*, the sides *P Z*, *P Y*, and *Z Y* (*p*).

Required to find angle *P* (the hour angle).

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (P\,Z \sim P\,Y)}{\sin P\,Z \sin P\,Y}$$

	°	′		
p =	37	11·6	nat. hav.	0·10170
(*P Z* ~ *P Y*) =	31	33·1	nat. hav.	0·07392
			nat. hav.	0·02778
			log hav.	8·44367
P Z =	40°	40·0′	log cosec	0·18598
P Y =	72	13·1	log cosec	0·02126
			log hav.	8·65091

	h.	m.	s.
H.A.T.S.,	1	37	43
E.,	—11	53	53
S.M.T.,	2	13	43	50
G.M.T.,	2	16	58	15
	3	14	25
	60		
4)	194	25	
Longitude (C),	48	36	15 W.

	°	′		
p =	37	11·6	nat. hav.	0·10170
(*P Z* ~ *P Y*) =	31	53·1	nat. hav.	0·07545
			nat. hav.	0·02625
			log hav.	8·41912
P Z =	40°	20·0′	log cosec	0·18894
P Y =	72	13·1	log cosec	0·02126
			log hav.	8·62932

	h.	m.	s.
H.A.T.S.,	1	35	17
E.,	—11	53	53
S.M.T.,	2	13	41	24
G.M.T.,	2	16	58	15
	3	16	51
	60		
4)	196	51	
Longitude (D),	49	12	45 W.

Projection on the Chart (Plate I.).

The longitudes being West, the meridians are numbered increasing from right to left. The four positions, *A*, *B*, *C*, and *D*, are then marked on the chart, each longitude in the latitude used for finding it.

To Find the Line of Position at the First Observation.—Having joined *A* and *B*, place the parallel rules on this line and take off its direction. You will find it to be about N. 45° E. and S. 45° W.

To Find the Sun's True Bearing at the First Observation.—Being a morning sight, the sun's true bearing is 90° to the Eastward of the first line of position. This makes it about S. 45° E.

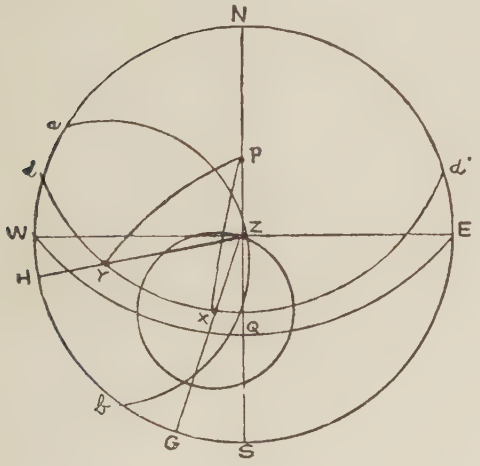
To Find the Ship's Position at the Second Observation.—From any point on *A B* lay off the run between the observations (N. 60° E., 40 miles), and from the extremity of this line draw a line parallel to *A B*. The point where this line cuts the *C D* line is the ship's position. When measured it is found to be Lat. 49° 28′ N., Long. 48° 51′ W.

NOTES

Worked Example II.

On 16th April, 1929, P.M. at ship, in latitude by account 50° 20′ N., longitude by account 179° 30′ W., when a chronometer (corrected) indicated Mean time at Greenwich (17th April) 00h. 38m. 42s., the observed altitude of the sun's L.L. was 48° 36·5′, and again, later on the same day when the same chronometer (corrected) indicated 04h. 28m. 46s., the observed altitude of the sun's L.L. was 21° 36′, the height of eye at each observation being 26 feet. The ship having made 26 miles on an 036° course during the interval between the observations, required the line of position and the true bearing of the sun when the first altitude was observed, and the position of the ship when the second altitude was observed.

Given Lat. 50° N.
Decl. 10° N.
1st obs. alt. 49°.
2nd obs. alt. 22°.



The circle *N E S W* represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
W Q E the equinoctial.
Z Q the latitude.
P Z the co-lat.
P the pole.
d Y X d′ the parallel of declination.
X the object at 1st observation.
G X its altitude.
Z X its zenith distance.
P X its polar distance.
Z P X its hour angle.
Y the object at 2nd observation.
H Y its altitude.
Z Y its zenith distance.
P Y its polar distance.
Z P Y its hour angle.

The small circle is a " circle of equal altitude " obtained from the first observation. The arc *a Z b* is part of a " circle of equal altitude " obtained from the second observation. As the ship is on both circles, she must be at one of their points of intersection (*Z*).

Worked Example II.

Run. N. 36° E., 26 miles.
D. Lat., 21·0′ N.

Lat. 1st obs., 50° 20′ N. . . . . co-lat. 39° 40′ = PZ
D. lat., 21 N.

Lat., 2nd obs., 50° 41′ N. . . . . co-lat. 39° 19′ = PZ

First Observation.

G M.T., 17d. 00h. 38m. 42s.

	d.	h.	°	′	
Decl.,	17	0	=10	13·5	N.
Corr. ·6 hr.,		+		·5	
Corr. decl.,			10	14·0	N.
			90	0	
Polar dist.,			79	46·0	= PX

	h.	m.	s.	h.	s.
E. 17d. 0h.,	.=12	00	14·9	0	=14·9
Corr. ·6 hr.,	.+		·4	2	=16·1
E. corrected,	12	00	15·3	2)	1·2
					·6
					·6
					·36

Obs. alt.,	48°	36·5′	
Dip.,	—		5·0
	48°	31·5	
Ref.,	—		·8
	48°	30·7′	
Plx.,	+		·1
S. dia.,	+		16·0
True alt.,	48°	46·8′	
	90	0	
Zen. dist.,	41°	13·2′	= ZX

Given in triangle PZX, the sides PZ (the co-lat.), PX (the polar dist.) and ZX (p) (the zenith distance). Required to find angle P (the hour angle).

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (PZ \sim PX)}{\sin PZ \quad \sin PX}$$

	°	′	
p =	41	13·2	nat. hav. 0·12391
$(PZ \sim PX)$ =	40	6·0	nat. hav. 0·11754
			nat. hav. 0·00637
			log. hav. 7·80440
PZ =	39°	40·0′	log cosec 0·19496
PX =	79	46·0	log cosec 0·00696
			log hav. 8·00632

	h.	m.	s.
H.A.T.S.,	0	46	15
E.,	.—12	00	15
S.M.T.,	16	12	46 00
G.M.T.,	17	00	38 42
	11	52	42
		60	
4)	712	42	
Longitude (A),	178	10	30 W.

	°	′	
p =	41	13·2	nat. hav. 0·12391
$(PZ \sim PX)$ =	40	27·0	nat. hav. 0·11951
			nat. hav. 0·00440
			log hav. 7·64364
PZ =	39°	19·0′	log cosec 0·19818
PX =	79	46·0	log cosec 0·00696
			log hav. 7·84878

	h.	m.	s.
H.A.T.S.,	0	38	34
E.,	.—12	00	15
S.M.T.,	16	12	38 19
G.M.T.,	17	00	38 42
	12	0	23
		60	
4)	720	23	
	180	05	45 W.
	360	00	00
Longitude (B),	179	54	15 E.

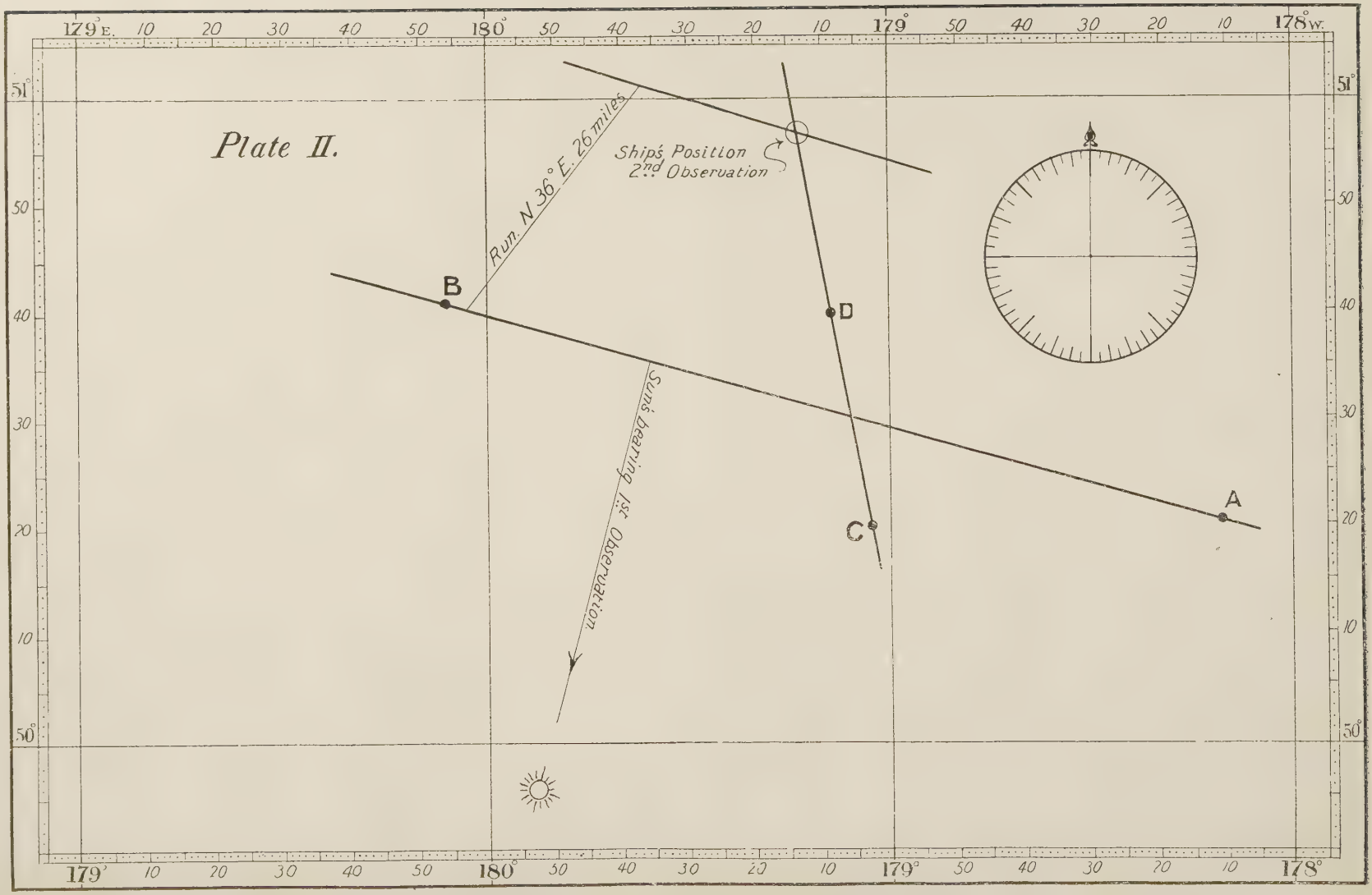


Plate II.
179° E.
180°
179°
178° W.
51°
50°
Run. N 36° E. 26 miles
Ships Position
2nd Observation
B
D
C
A
Suns bearing at Observation

Worked Example II.

Second Observation.

G.M.T., 17d. 04h. 28m. 46s.

	d.	h.	°	′		h.	m.	s.	h.	s.		°	′
Decl.,	17	4 =	10	17·1 N.	E. 17d. 4h.	= 12	00	17·3	4 =	17·3	Obs. alt.,	21	36·0
Corr. ·5 hr.,		+		·4	Corr. ·5 hr.,	+		·3	6 =	18·5	Dip,	−	5·0
Corr. decl.,			10	17·5 N.	E. corrected,	12	00	17·6	2)	1·2		21	31·0
			90	0						·6	Ref.,	−	2·4
Polar dist.,			79	42·5 = *P Y*						·5		21	28·6
										·30	Plx.,	+	·1
											S. dia.,	+	16·0
											True alt.,	21	44·7
												90	0
											Zen. dist.,	68	15·3′ = *Z Y* = *p*

Hav. $P = \dfrac{\text{hav. } p - \text{hav. } (P\,Z \sim P\,Y)}{\sin P\,Z \;\; \sin P\,Y}$

	°	′			°	′		
p =	68	15·3	nat. hav.	0·31476	68	15·3	nat. hav.	0·31476
(*P Z* ~ *P Y*) =	40	2·5	nat. hav.	0·11721	40	23·5	nat. hav.	0·11918
			nat. hav.	0·19755			nat. hav.	0·19558
			log hav.	9·29567			log. hav.	9·29133
P Z =	39	40·0	log cosec	0·19496	39	19·0	log cosec	0·19818
P Y =	79	42·5	log cosec	0·00704	79	42·5	log cosec	0·00704
			log hav.	9·49767			log hav.	9·49655

	h.	m.	s.		h.	m.	s.
H.A.T.S.,	4	32	54·5	H.A.T.S.,	4	32	30·5
E.,	−12	00	17·6	E.,	−12	00	17·6
S.M.T.,	16	16	32	37	16	16	32	13
G.M.T.,	17	04	28	46	17	04	28	46
	11	56	9		11	56	33
	60				60		
	4) 716	9			4) 716	33	
Longitude (C),	179	02	15 W.	Longitude (D),	179	08	15 W.

PROJECTION ON THE CHART (see Plate II.).

Notice carefully the way the meridians are numbered. When the Longitudes are near 180°, with some East and some West, the meridians must be numbered thus :—

177 E. 178 E. 179 E. 180 179 W. 178 W. 177 W.

When near the meridian of Greenwich, mark them thus :—

3 W. 2 W. 1 W. 0 1 E. 2 E. 3 E.

Lay off the positions *A* and *B*, being careful to see that each longitude is laid off in the latitude used for finding it. A straight line joining *A* and *B* is the first position line.

Lay off *C* and *D*. A straight line joining *C* and *D* is the second position line.

The first observation being taken in the afternoon, the sun's bearing at that time will be 90° to the Westward of the first position line.

From any point on *A B* lay off the run (N. 36° E. 26 miles). From the extremity of this line draw a line parallel to *A B*. The point where this line cuts the *C D* line is the ship's position at the second observation.

Complete Answer.

Line of position, 1st observation :—N. 74° W. and S. 74° E.
Sun's true bearing, 1st observation :—S. 16° W.
Ship's position, 2nd observation :—Lat. 50° 56′ N., Long. 179° 13′ W.

DOUBLE ALTITUDE (SUMNER'S METHOD).

Examples for Exercise XIII.

(1) On 7th August, 1929, A.M. at ship, in latitude by account 49° 50′ N., longitude by account 4° W., when a chronometer (corrected) indicated Mean time at Greenwich 09h. 08m. 40s., the observed altitude of the sun's L.L. was 38° 18′, and again, P.M. on the same day when the same chronometer (corrected) indicated 15h. 15m. 55s., the observed altitude of the sun's L.L. was 41° 21′, height of eye at each observation being 26 feet. The ship having made 30 miles on a 113° course during the interval between the observations, required the line of position when the first altitude was observed, also the true bearing of the sun and the ship's position when the second altitude was observed.

(2) On 24th September, 1929, A.M. at ship, in latitude by account 51° 15′ N., longitude by account 165° E., when a chronometer (corrected) indicated Mean time at Greenwich (23rd September) 22h. 19m. 10s., the observed altitude of the sun's L.L. was 29° 05′, and again, P.M. on the same day when the same chronometer (corrected) indicated 01h. 56m. 49s., the observed altitude of the sun's L.L. was 36° 36′, height of eye at each observation 23 feet. The ship having made 40 miles on a 300° course during the interval between the observations, required the line of position and the true bearing of the sun when the first altitude was observed, and the position of the ship when the second altitude was observed.

(3) On 15th June, 1929, P.M. at ship, in latitude by account 50° 12′ N., longitude by account 179° 30′ E., when a chronometer (corrected) indicated Mean time at Greenwich 02h. 02m. 19s., the observed altitude of the sun's L.L. was 54° 17′, and again, later on the same day when the same chronometer (corrected) indicated 06h. 32m. 28s., the observed altitude of the sun's L.L. was 12° 20′, the height of eye at each observation being 24 feet. The ship having made 46 miles on a 118° course during the interval between the observations, required the line of position when the first altitude was observed, also the sun's true bearing and position of the ship when the second altitude was observed.

Examples XIV. for Projection on Chart.

It will not be necessary for you to go through the whole of the working of more than one or two Sumners. You may, however, want more practice in plotting them off on the chart. Herewith a few examples for projection only.

(Four longitudes worked out.)

No. 1.

First Observation (before Noon).		Second Observation (after Noon).	
A. Lat. 49° 50′ N.	Long. 1° 10′ W.	C. Lat. 49° 50′ N.	Long. 0° 14′ W.
B. Lat. 50° 20′ N.	Long. 0° 28′ W.	D. Lat. 50° 20′ N.	Long. 1° 38′ W.

The run in the interval was West (true) distance 26 miles. Required the line of position and sun's true bearing at the time of taking the first observation, also the ship's position at the time of taking the second observation.

No. 2.

First Observation (Morning).		Second Observation (Morning).	
A. Lat. 51° 20′ N.	Long. 2° 16′ E.	C. Lat. 51° 20′ N.	Long. 0° 45′ E.
B. Lat. 52° 0′ N.	Long. 2° 47′ E.	D. Lat. 52° 0′ N.	Long. 2° 47′ E.

In the interval between the observations the ship made N. 70° W. (true) distance 31 miles. Required the line of position at the first observation, also the sun's true bearing and ship's position at the second observation.

No. 3.

First Observation (before Noon).		Second Observation (after Noon).	
A. Lat. 50° 0′ N.	Long. 1° 40′ W.	C. Lat. 50° 0′ N.	Long. 0° 15′ E.
B. Lat. 50° 30′ N.	Long. 1° 10′ W.	D. Lat. 50° 30′ N.	Long. 0° 15′ W.

The course and distance made good in the interval was S. 60° E. (true) 32 miles. Required the line of position at the first observation, also the sun's true bearing and ship's position at the second observation.

DOUBLE ALTITUDE (MARCQ ST. HILAIRE METHOD).

This is another method of finding the latitude and longitude of a ship by means of position lines obtained from two observations of the sun or from observations of other celestial bodies. Either sun, star, or planet may be used in conjunction with each other when they are in suitable positions. There should be considerable difference between their bearings, so that the corresponding position lines make a good "cut." These remarks also apply to Sumner's method. Up to the present time the sun has always been observed in that problem.

Observations of two different bodies may be taken at the same time, in which case they are called "Simultaneous altitudes." More often, however, two observations are given, together with the ship's run in the interval.

An approximate latitude and longitude are given at the time of taking the first observation, and by applying to it the run in the interval we obtain the approximate (D.R.) position at the time of taking the second observation. We then have the ship's position by D.R. at **both** observations.

We are also given the G.M.T. and the observed altitude of the object at each observation. By correcting the observed altitude in the ordinary way we obtain the **true** altitude.

Then by means of the object's hour angle and other elements as shown in the worked examples, we calculate the object's approximate zenith distance and thence its approximate altitude at both observations.

We also find the true bearing of the object at each observation by means of the Time azimuth tables or Blackburne's tables, the latter being suitable for all latitudes and declinations.

If the approximate calculated altitude agrees with the true altitude obtained by means of the sextant at either observation, we know that we have correctly estimated our angular distance from the object at that observation, and that the corresponding position line is where we expected it to be. It does not follow that the D.R. position is the correct one. It may be **anywhere** on the position line.

If the true altitude obtained by means of the sextant is greater than the approximate calculated one, we must be nearer to the object than we thought we were; if the true altitude is smaller than the approximate calculated one, we must be further away from it. The difference in the value of the two altitudes gives us the "*intercept towards*" or "*intercept away*" from the object, as the case may be.

We now have all the elements required for the projection on the chart, which is done as follows:—

Lay off the ship's position by D.R. at the **second** observation.

Through it draw lines in the direction of the true bearing of the object at **both** observations.

From the D.R. position marked on the chart, lay off the value of the first intercept along the line of the object's bearing at the first observation (towards the object or away from the object as the case may be), and make a mark. Through this mark draw a line at right angles to the object's bearing. This is a position line parallel to the position line at the first observation. (The first position line is not shown on the chart.)

In the same manner we then draw a position line for the second observation.

The intersection of these two lines indicates the position of the ship at the time of taking the second observation.

(*Detailed explanation with Worked Example I.*)

DOUBLE ALTITUDE (MARCQ ST. HILAIRE METHOD).

The latitude and longitude by account are given at the time of taking the first observation, also the run in the interval between the observations.

From the traverse table take out the D. lat. and Departure corresponding to the run, turn the departure into difference of longitude, and find the latitude and longitude by account (the D.R. position) at the second observation.

Working of the First Observation.

1. The G.M.T. being given, copy down and correct the value of E. when the sun is observed, but R. when a star is observed.
2. Find the object's hour angle, polar distance, and true altitude.
3. With the latitude at first observation, object's declination and hour angle (A.T. ship in the case of the sun), find its true bearing from the Time Azimuth Tables.
4. By means of the haversine formula, calculate the object's approximate zenith distance. Subtract from 90° to get its altitude.
5. Find the difference between this approximate calculated altitude and the true altitude obtained by means of the sextant, and call it the " first intercept."
6. Name the intercept **towards** the object when the true altitude is greater than the approximate calculated altitude, but **away from** the object when the true altitude is smaller.

This completes the calculations for the first observation.

Working of the Second Observation.

Using the time, D.R. position, and all the elements at the second observation, find the object's true bearing and second intercept as explained in 1 to 6 above.

We then have all the elements necessary for the final plotting of the position lines on the chart.

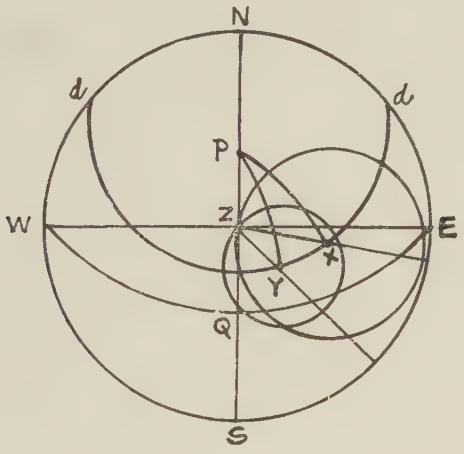
The calculations are given on the following pages, and the projection on the chart is shown and explained.

Worked Example I.

On 13th June, 1929, in latitude by account 49° 10′ N., longitude by account 8° 25′ W., when a chronometer (corrected) indicated Mean time at Greenwich 08h. 41m. 23s., the observed altitude of the sun's L.L. was 37° 47′, and again later on the same day, when the same chronometer (corrected) indicated 10h. 44m. 48s., the observed altitude of the sun's L.L. was 55° 57·6′, height of the eye at each observation being 38 feet. The ship having made 23 miles on a 313° course during the interval between the observations, required the position of the ship at the time of taking the second observation.

To Draw the Figure.

As we have given the latitude and altitude, and can take the declination (approximately) from the *Nautical Almanac*, this figure is constructed in the same way as when worked by Sumner's method.



Explanation of the Figure.

(To be written at the examination.)

The large circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
P the elevated pole.
W Q E the equinoctial.
d d the parallel of declination.
Z Q the latitude.
P Z the co-latitude.
X the object at 1st observation.
P X its polar distance.
Z X its zenith distance.
Z P X its hour angle.
Y the object at 2nd observation.
P Y its polar distance.
Z Y its zenith distance.
Z P Y its hour angle.

The two smaller circles are circles of equal zenith distance drawn round the sun at each observation. To have obtained those zenith distances the observer must have been on both of the circles. His position is at their point of intersection at *Z*.

Worked Example I.

Run N. 47° W. 23 miles. D. Lat. 15·7 Dep. 16·8

D.R. pos. at 1st obs.:—Lat. 49° 10′ N. . . co-lat. 40° 50′ = *P.Z.* . Long. 8° 25′ W.
D. Lat. 16 N. D. Long. 26 W.

D.R. pos. at 2nd obs.:—Lat. 49 26 N. . . co-lat. 40 34 = *P.Z.* . Long. 8 51 W.

First Observation.

Long. W. 8° 25′ = 33m. 40s.

		d.	h.	m.	s.
G.M.T.,	.	13	08	41	23
Long. W.,	.—			33	40
S.M.T.,	.		08	07	43
E.,	.+		12	00	15·3
H.A.T.S.,	.		20	07	58·3
			24	00	00
Ely. H.A.,	.		3	52	1·7 = *P*

	d.	h.	h.	m.	s.		s.
E., . .	13	08	=12	00	15·7	8h. =	15·7
Corr. ·7 hr.,			—		·4	10h. =	14·7
E. corrected,			12	00	15·3	2)	1·0
							·5
							·7
							·35

	d.	h.	°	′		′
Decl., .	13	08	=23	11·8	N.	8h. = 11·8
Corr. ·7 hr.,			+	·1		10h. = 12·1
Corr. decl.,			23	11·9	N.	2) ·3
			90	00		·15
Polar dist.,			66	48·1	= *P X*	·7
						·105

	°	′
P Z =	40	50
P X =	66	48·1
(*P Z* ~ *P X*) =	25	58·1

	°	′
Obs. alt., .	37	47·0
Dip, . .—		6·0
	37	41·0
Ref., . .—		1·2
	37	39·8
Plx., . .+		·1
S. dia. . .+		15·8
True alt., .	37	55·7

From Time Azimuth Tables.

Lat. 49° 10′ N.
Decl. 23 12 N.
A.T. ship, 8h. 8m. A.M. } gives sun's true bearing, N. 98° E.

Given in spherical triangle *P Z X*, the sides *P Z* (the co-lat.), *P X* (the polar distance), and angle *P* (the hour angle).

Required to find side *Z X* (*p*) (the zenith distance).

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (P\,Z \sim P\,X)}{\sin P\,Z \sin P\,X}.$$

Hav. *P* sin *P Z* sin *P X* = hav. *p* − hav. (*P Z* ~ *P X*)
Hav. *P* sin *P Z* sin *P X* + hav. (*P Z* ~ *P X*) = hav. *p*.

P = 3 h. 52m. 1·7s.	log. hav.	9·37153	
P Z = 40° 50′	log. sin	9·81549	
P X = 66 48·1	log sin	9·96338	
	log hav.	9·15040	
	nat. hav.	0·14138	
(*P Z* ~ *P X*) = 25 58·1	nat. hav.	0·05048	
p = 51 57·3	nat. hav.	0·19186	

	°	′
Approx. zenith distance, .	51	57·3
	90	0
Approx. calculated alt., . .	38	2·7
True alt. by sextant, . .	37	55·7
Intercept away from sun, .		7·0

Worked Example I.

Second Observation.

Long. W.		d.	h.	m.	s.
8° 51′	G.M.T.,	13	10	44	48
4	Long. W.,			35	24
35m. 24s.	S.M.T.,	13	10	09	24
	E.,		12	00	14·3
	H.A.T.S.,		22	09	38·3
			24	00	00
	Ely. H.A.,		1	50	21·7 = P

	d.	h.	h.	m.	s.		s.
E.,	13	10	=12	00	14·7	10h. =	14·7
Corr. ·7 hr.,			—		·4	12h. =	13·6
E. corrected,			12	00	14·3	2)	1·1
							·55
							·7
							·385

	d.	h.	°	′		′
Decl.,	13	10	=23	12·1 N.	10h. =	12·1
Corr. ·7 hr.,			+	·1	12h. =	12·4
Corr. decl.,			23	12·2 N.	2)	·3
			90	00		·15
Polar dist.,			66	47·8 = $P\,Y$		·7
						·105

		°	′
$P\,Z$ = 40° 34′	Obs. alt.,	55	57·6
$P\,Y$ = 66 47·8	Dip.,	—	6·0
$P\,Z \sim P\,Y$ = 26 13·8		55	51·6
	Ref.,	—	·6
		55	51·0
	Plx.,	+	·1
	S. dia.,	+	15·8
	True alt.,	56	06·9

From Time Azimuth Tables.

Lat. 49° 26′ N.
Decl. 23° 12′ N.
A.T. ship, 10h. 10m. A.M.
} gives sun's true bearing N. 131° E.

Given in spherical triangle $P\,Z\,Y$ the sides $P\,Z$ (the co-lat.), $P\,Y$ (the polar distance), and angle P (the hour angle).

Required to find side $Z\,Y$ (p) (the zenith distance).

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (P\,Z \sim P\,Y)}{\sin P\,Z \sin P\,Y}.$$

$$\text{Hav. } P \sin P\,Z \sin P\,Y = \text{hav. } p - \text{hav. } (P\,Z \sim P\,Y).$$
$$\text{Hav. } P \sin P\,Z \sin P\,Y + \text{hav. } (P\,Z \sim P\,Y) = \text{hav. } p.$$

	h. m. s.		
P =	1 50 21·7	log hav.	8·75480
$P\,Z$ =	40° 34′	log sin	9·81314
$P\,Y$ =	66 47·8	log sin	9·96337
		log hav.	8·53131
		nat. hav.	0·03399
$(P\,Z \sim P\,Y)$ =	26° 13·8	nat. hav.	0·05148
p =	34 0	nat. hav.	0·08547

	°	′
Approx. zenith dist.,	34	0
	90	0
Approx. calculated alt.,	56	0
True alt. by sextant,	56	6·9
Intercept towards sun,		6·9′

		°	′
Ship's pos. at 2nd obs.	Lat.	49	4 N.
	Long.	9	7 W.

Worked Example I.—*Continued.*

Projection on the Chart.

(See Plate opposite.)

Lay off on the chart the ship's position by dead reckoning at the time of taking the second observation (Lat. 49° 26′ N., Long. 8° 51′ W.). Make a mark.

Through this mark draw a line in the direction of the sun's true bearing at the *first* observation (N. 98° E. or S. 82° E.).

Measure along this line (from the mark) the amount of the *first* intercept. In this example it is 7·0′ *away from the sun.*

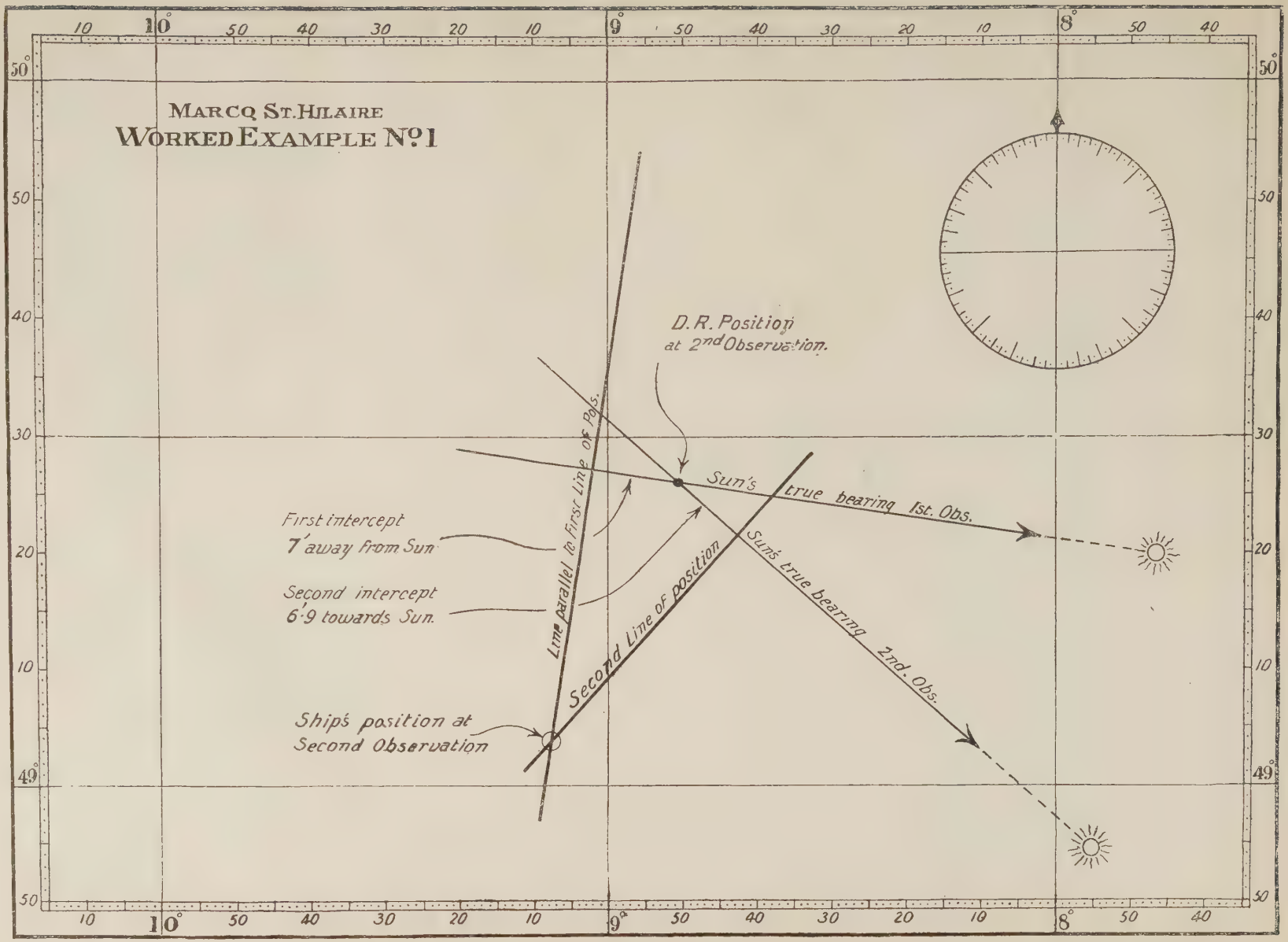
From the end of the intercept just measured, draw a line at right angles to the sun's true bearing. This is a line parallel to the line of position at the first observation. (The *actual* line of position at the first observation is not shown.)

Now from the same mark (the dead reckoning position at the second observation) draw a line in the direction of the sun's true bearing at the *second* observation (N. 131° E. or S. 49° E.).

Measure along this line (from the same mark), the amount of the *second* intercept. In this case it is 6·9′ *towards the sun.*

From the end of the intercept just measured, draw a line at right angles to the sun's true bearing. This is the line of position at the second observation.

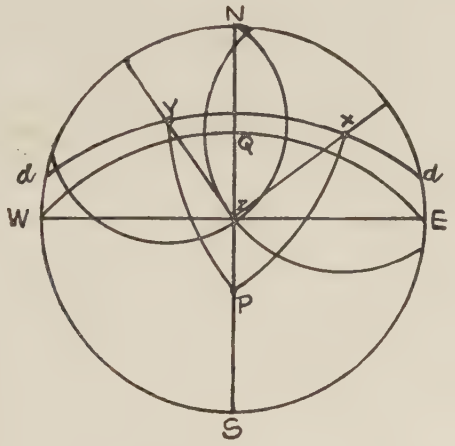
The point where this second line of position intercepts the line parallel to the first line of position is the position of the ship at the time of taking the second observation. It will be found to be Lat. 49° 4′ N., Long. 9° 7′ W.


MARCQ ST. HILAIRE
WORKED EXAMPLE No. 1
D.R. Position at 2nd Observation.
Sun's true bearing 1st. Obs.
First intercept 7' away from Sun
Second intercept 6·9 towards Sun.
Line parallel to First Line of Pos.
Second Line of position
Sun's true bearing 2nd. Obs.
Ship's position at Second Observation
10° 50 40 30 20 10
9° 50 40 30 20 10
8° 50 40
50° 40 30 20 10 49°

[To be inserted facing page 156.

Worked Example II.

On 13th April, 1929, in latitude by account 49° 30′ S., longitude by account 69° E., when a chronometer (corrected) indicated 04h. 06m. 48s. Mean time at Greenwich, the observed altitude of the sun's L.L. was 17° 37′, and again on the same day when the same chronometer (corrected) indicated 09h. 17m. 28s., the observed altitude of the sun's L.L. was 26° 6·2′, the index error of sextant being 2′ 12″ to add, and the height of eye 26 feet at both observations. The ship having made 40 miles on a 114° course during the interval between the observations, required the line of position at the first observation, and the latitude and longitude of the ship at the second observation.



Explanation of the Figure.

(To be written at the examination.)

The circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
N Z S the observer's meridian.
W Z E the prime vertical.
P the elevated pole.
W Q E the equinoctial.
d d the parallel of declination.
Z Q the latitude.
P Z the co-latitude.
X the object at 1st observation.
P X its polar distance.
Z X its zenith distance.
Z P X its hour angle.
Y the object at 2nd observation.
P Y its polar distance.
Z Y its zenith distance.
Z P Y its hour angle.

The arc drawn round the object at each observation has a radius equal to the zenith distance when the altitude was observed. To have obtained these zenith distances the observer must have been on both of the arcs, his position being indicated by their point of intersection at *Z*.

Worked Example II.

Run S. 66° E. 40 miles. D. Lat. 16·3 Dep. 36·5

D.R. pos. at 1st obs. :—Lat. 49° 30′ S. . . co-lat. 40° 30′ = PZ . Long. 69° 0′ E.
D. Lat. 16 S. D. Long. 56 E.

D.R. pos. 2nd obs. :— Lat. 49 46 S. . . co-lat. 40 14 = PZ . Long. 69 56 E.

First Observation.

Long. E. 69° 0′ + 4 = 60) 276 0 = 4h. 36m. 0s.

	d.	h.	m.	s.
G.M.T.,	13	04	06	48
Long. E., +		4	36	00
S.M.T.,		8	42	48
E., +		11	59	17·7
H.A.T.S.,		20	42	05·7
		24	00	00
Ely. H.A.,		3	17	54·3 = P

	d.	h.	h.	m.	s.
E.,	13	04	= 11	59	17·6
Corr. ·1 hr.,			+		·1
E. corrected,			11	59	17·7

	d.	h.	°	′
Decl.,	13	04	= 8	51·0 N.
Corr. ·1 hr.,			+	·1
Corr. decl.,			8	51·1 N.
			90	00
Polar dist.,			98	51·1 = PX

	°	′
Obs. alt.,	17	37
Ind. error, +		2·2
	17	39·2
Dip., −		5·0
	17	34·2
Ref., −		3·0
	17	31·2
Plx., +		·1
S. dia., +		16·0
True alt.,	17	47·3

From Time Azimuth Tables.

Lat. 49° 30′ S.
Decl., 8° 51′ N. } gives sun's true bearing, S. 128° E.
A.T. ship, 8h. 42m. A.M. } 90

First line of position, S. 38° E.

To Find Side ZX (p) (the zen. dist.)

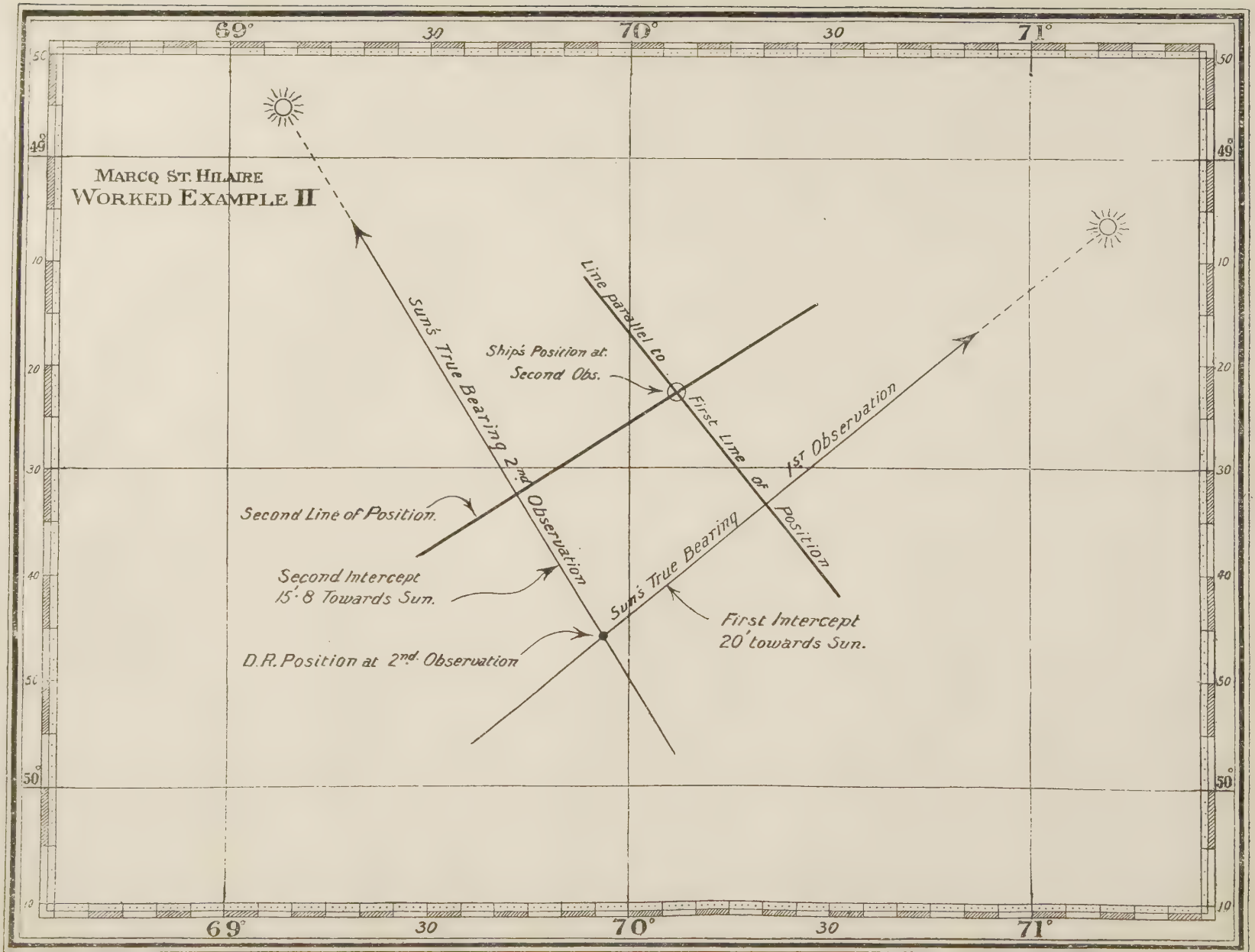
$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (PZ \sim PX)}{\sin PZ \sin PX}$$

Hav. P sin PZ sin PX = hav. p − hav. ($PZ \sim PX$)
Hav. P sin PZ sin PX + hav. ($PZ \sim PX$) = hav. p

	°	′
PZ =	40	30
PX =	98	51·1
$PZ \sim PX$ =	58	21·1

	h. m. s.		
P =	3 17 54·3	log hav.	0·24333
PZ =	40° 30′	log sin	9·81254
PX =	98 51·1	log sin	9·99480
		log hav.	9·05067
		nat. hav.	0·11238
($PZ \sim PX$) =	58° 21·1′	nat. hav.	0·23765
p =	72 32·7	nat. hav.	0·35003

	°	′
Appx. zen. dist.,	72	32·7
	90	0
Appx. calculated alt.,	17	27·3
True alt. by sextant,	17	47·3
Intercept towards sun,		20·0′


69°
30
70°
30
71°
50
49°
10
20
30
40
50
50°
MARCQ ST. HILAIRE
WORKED EXAMPLE II
Sun's True Bearing 2nd Observation
Line parallel to
First Line of
1st Observation
Position
Ship's Position at
Second Obs.
Second Line of Position.
Second Intercept
15·8 Towards Sun.
D.R. Position at 2nd Observation
Sun's True Bearing
First Intercept
20' towards Sun.

Worked Example II.

Second Observation.

Long. E.		d.	h.	m.	s.
69° 56′	G.M.T.,	13	09	17	28
4	Long. E., +		4	39	44
6,0)27,944	S.M.T.,		13	57	12
	E., +		11	59	21
4h. 39m. 44s.	H.A.T.S.,		1	56	33 = P

	d.	h.	h.	m.	s.
E.,	13	08	= 11	59	20·2
Corr. 1·3 hr.,			+		·8
E. corrected,			11	59	21·0

	d.	h.	°	′	
Decl.,	13	08	= 8	54·6	N.
Corr. 1·3 hr.,			+	1·2	
Corr. decl.,			8	55·8	N.
			90	00	
Polar dist.,			98	55·8	= PY

	°	′
Obs. alt.,	26	06·2
Ind. err., +		2·2
	26	08·4
Dip, −		5·0
	26	03·4
Ref., −		1·9
	26	01·5
Plx., +		·1
S. dia., +		16·0
True alt.,	26	17·6

From Time Azimuth Tables.

Lat. 49° 46′ S.
Decl., 8° 56′ N.
S.A.T., 1h. 57m. P.M.
} gives sun's true bearing S. 148° W., N. 32° W.

To Find Side ZY (p) (the zen. dist.).

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (PZ \sim PY)}{\sin PZ \sin PY}.$$

Hav. $P \sin PZ \sin PY = \text{hav. } p - \text{hav. } (PZ \sim PY)$.
Hav. $P \sin PZ \sin PY + \text{hav. } (PZ \sim PY) = \text{hav. } p$.

	°	′
PZ =	40	14
PY =	98	55·8
$(PZ \sim PY)$ =	58	41·8

	h.	m.	s.		
P =	1	56	33	log hav.	8·80122
PZ =	40°	14′		log sin	9·81017
PY =	98	55·8		log sin	9·99470
				log hav.	8·60609
				nat. hav.	0·04038
$(PZ \sim PY)$ =	58	41·8		nat. hav.	0·24021
p =	63	58·2		nat. hav.	0·28059

	°	′
Appx. zen. dist.,	63	58·2
	90	0
Appx. calculated alt.,	26	1·8
True alt. by sextant,	26	17·6
Intercept towards sun		15·8′

Answer.

Line of pos. 1st ob. :—N. 38° W. and S. 38° E.
Ship's position 2nd obs. { Lat. 49° 23′ S. / Long. 70 7 E.

DOUBLE ALTITUDE.

MARCQ ST. HILAIRE METHOD—STAR.

The principles underlying the Marcq St. Hilaire method of finding a ship's position by means of altitudes of a star are exactly the same as when using the sun. Whatever objects may be used, it is still the method of Marcq St. Hilaire.

The projection on the chart is also the same.

The only difference in the working is that the star's hour angle must be used instead of that of the sun, both for calculating the altitude and finding the star's true bearing from the azimuth tables ; also that the star's altitude must be corrected for index error (if any), dip, and refraction only.

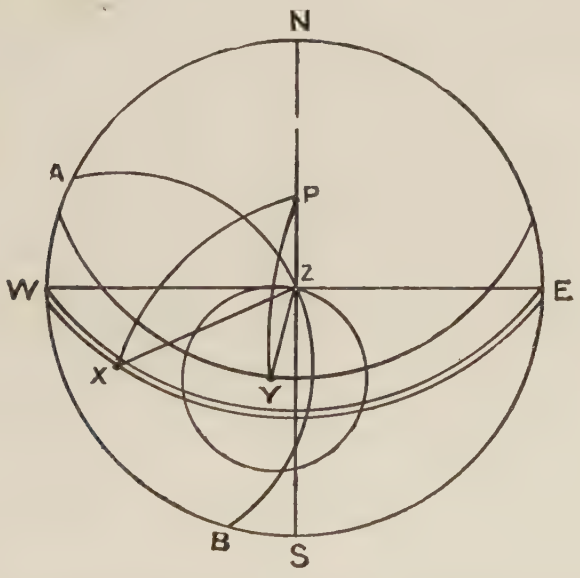
A star and the sun may also be used in the same problem to find the position lines and the latitude and longitude of the ship as in Worked Example III. Do not be doubtful because the position of the object at the second observation is to the Eastward of the position at the first observation. **Two different objects are being used**, the sun with a small altitude and a star observed about two hours after sunset. The object at the second observation being in a more Easterly position than the one at the first observation is a common occurrence when two objects are observed, but would be impossible if two altitudes were taken of the same object.

DOUBLE ALTITUDE.

(Observation of Sun and Star.)

Worked Example III.

On 26th September, 1929, in latitude by account 51° 10′ N., longitude by account 7° 30′ W., when a chronometer (corrected) indicated Mean time at Greenwich 16h. 30m. 01s., the observed altitude of the sun's L.L. was 15° 50′, and later on the same day when the same chronometer (corrected) indicated 20h. 28m. 50s., the observed altitude of the star *α Aquilæ* (Altair) West of the meridian was 46° 47′, index error 1′ 30″ to subtract, and height of eye 35 feet at both observations. The ship having made 43 miles on an 085° course during the interval between the observations, required the position of the ship at the time of taking the second observation.



EXPLANATION OF THE FIGURE.

(To be written at the examination.)

The large circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon, etc., as in preceding examples.

X is the position of the sun at the first observation, the arc *A B* being an arc of the circle representing its zenith distance.

Y is the position of the star Altair at the second observation, the small circle representing its zenith distance.

The observer having obtained both zenith distances, he must be on both circles, his actual position being at their point of intersection at *Z*.

Worked Example III.

Run N. 85° E.
43 miles.
D. Lat. 3·7
Dep. 42·8

D.R. pos. at 1st obs. :— Lat. 51° 10′ N. . . co-lat. 38° 50′ = PZ . Long. 7° 30′ W.
D. Lat. 4 N. D. Long. 1 8 E.

D.R. pos. at 2nd obs. :— Lat. 51 14 N. . . co-lat. 38 46 = PZ . Long. 6 22 W.

First Observation (the Sun).

Long. W.		d.	h.	m.	s.
7° 30′	G.M.T., .	26	16	30	01
4	Long. W., . −			30	00
30m. 0s.	S.M.T., .		16	00	01
	E., .. .+		12	08	37·1
	H.A.T.S., .		4	8	38·1 = P

	d.	h.	h.	m.	s.
E., . . .	26	16	=12	08	36·7
Corr. ·5 hr., . .			+		·4
E. corrected, . .			12	08	37·1

	d.	h.	°	′
Decl., . . .	26	16	= 1	13·2 S.
Corr. ·5 hr. . .			+	·5
Corr. decl., . .			1	13·7 S.
			90	00
Polar dist., . .			91	13·7 = PX

	°	′
Obs. alt., ...	15	50
Ind. err., ...−		1·5
	15	48·5
Dip., ...−		5·8
	15	42·7
Ref., ...−		3·3
	15	39·4
Plx., ...+		·1
S. dia., ...+		16·0
True alt., ...	15	55·5

From Time Azimuth Tables.

Lat. 51° 10′ N.
Decl., 1° 14′ S.
Hour angle, 4h 8m. 38s. W.
} gives sun's true bearing, N. 113° W. S. 67° W.

To Find Side ZX (p) (the zen. dist.).

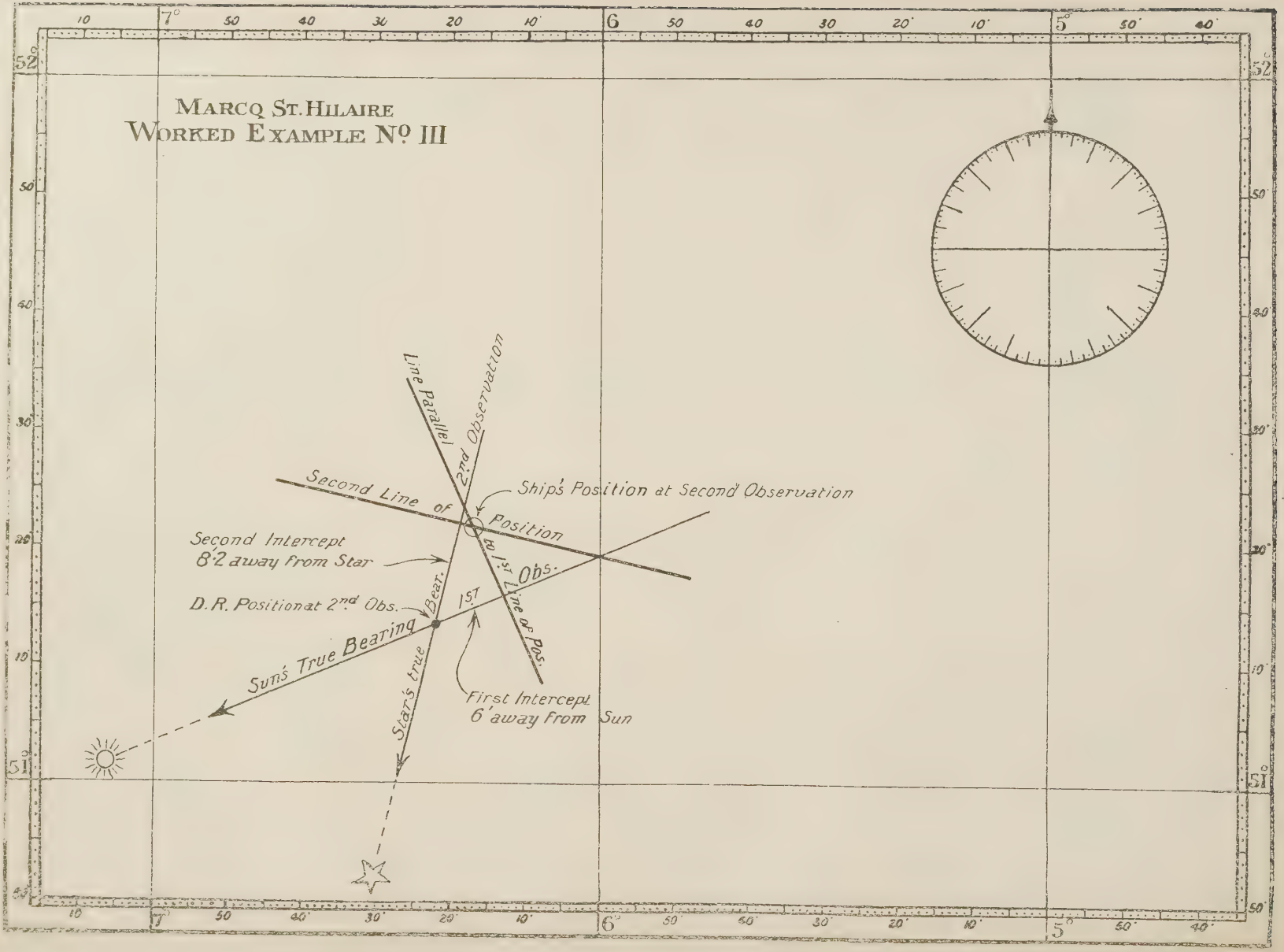
$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (PZ \sim PX)}{\sin PZ \sin PX}.$$

Hav. P sin PZ sin PX = hav. p − hav. ($PZ \sim PX$)
Hav. P sin PZ sin PX + hav. ($PZ \sim PX$) = hav. p.

	°	′
PZ =	38	50
PX =	91	13·7
($PZ \sim PX$) =	52	23·7

	h.	m.	s.		
P =	4	8	38·1	log. hav.	9·42568
PZ =	38°	50′		log sin	9·79731
PX =	91	13·7		log sin	9·99990
				log. hav.	9·22289
				nat. hav.	0·16707
($PZ \sim PX$) =	52°	23·7′		nat. hav.	0·19490
p =	73	58·5		nat. hav.	0·36197

	°	′
Approx. zenith dist., . .	73	58·5
	90	0
Approx. calculated alt., . .	16	1·5
True alt. by sextant, . .	15	55·5
Intercept away from sun, . .		6′


MARCQ ST. HILAIRE
WORKED EXAMPLE No III
Line Parallel 2nd Observation
Second Line of Position
Ship's Position at Second Observation
Second Intercept 8·2 away from Star
D.R. Position at 2nd Obs.
Bear. 1st
Sun's True Bearing
Star's true
First Intercept 6' away from Sun
to 1st Obs.
Line of Pos.

Worked Example III.

Second Observation (star Altair).

Long. W.		d.	h.	m.	s.
6° 22′	G.M.T.,	26	20	28	50
4	Long. W.,	—		25	28
25m. 28s.	S.M.T.,		20	03	22
	R.,	+	00	20	36·5
	R.A.M.,		20	23	58·5
	Star's R.A.,		19	47	21
	Star's H.A.,			36	37·5 W = P

	d.	h.	h.	m.	s.
R.,	26	20	=00	20	31·7
Corr. 29m.,			+		4·8
R. corrected,			00	20	36·5

	°	′	
Star's decl.,	8	40·9	N.
	90	00	
Polar dist.,	81	19·1	= PY

	°	′
Obs. alt.,	46	47
Ind. err.,	—	1·5
	46	45·5
Dip,	—	5·8
	46	39·7
Ref.,	—	·9
True alt.,	46	38·8

From Time Azimuth Tables.

Lat., 51° 14′ N.
Decl., 8° 41′ N.
Hour angle, 0h. 36m. 38s. W.
} gives star's true bearing N. 166·7° W., S. 13° W.

To Find Side ZY (p) (the zen. dist.).

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (PZ \sim PY)}{\sin PZ \sin PY}.$$

Hav. $P \sin PZ \sin PY = \text{hav. } p - \text{hav. } (PZ \sim PY)$.
Hav. $P \sin PZ \sin PY + \text{hav. } (PZ \sim PY) = \text{hav. } p$.

	°	′
PZ =	38	46
PY =	81	19·1
$(PZ \sim PY)$ =	42	33·1

	h.	m.	s.		
P =	0	36	37·5	log hav.	7·80420
PZ =	38°	46′		log sin	9·79668
PY =	81	19·1		log sin	9·99500
				log hav.	7·59588
				nat. hav.	0·00394
$(PZ \sim PY)$ =	42°	33·1′		nat. hav.	0·13167
p =	43	13·0		nat. hav.	0·13561

	°	′
Approx. zenith dist.,	43	13·0
	90	0
Approx. calculated alt.,	46	47·0
True alt. by sextant,	46	38·8
Intercept away from star,		8·2′

Ship's position 2nd obs. { Lat. 51° 22′ N. Long. 6 17 W.

Examples for Exercise XV.

Two Altitudes of the Sun.

(1) On 21st May, 1929, A.M. at ship, in latitude by account 49° N., longitude by account 170° E., when a chronometer (corrected) indicated Mean time at Greenwich (20th May) 19h. 06m. 52s., the observed altitude of the sun's L.L. was 19° 59′, and again during the same morning, when the same chronometer (corrected) indicated 23h. 06m. 50s., the observed altitude of the sun's L.L. was 55° 31·6′, the height of the eye at each observation being 35 feet. The ship having made 36 miles on a 295° course during the interval between the observations, required the position of the ship when the second altitude was observed.

Two Altitudes of the Sun.

(2) On 20th September, 1929, in latitude by account 42° S., longitude by account 149° E., when a chronometer (corrected) indicated Mean time at Greenwich 00h. 07m. 40s., the observed altitude of the sun's L.L. was 40° 00′, and again later on the same day when the same chronometer (corrected) indicated 04h. 04m. 52s., the observed altitude of the sun's L.L. was 37° 41·5′, height of the eye at each observation being 34 feet. The ship having made 30 miles on an 060° course during the interval between the observations, required the line of position, sun's true bearing, and latitude and longitude of the ship when the second altitude was observed.

Two Altitudes of the Sun.

(3) On 15th April, 1929, A.M. at ship, in latitude by account 50° 20′ N., longitude by account 33° 30′ W., when a chronometer (corrected) indicated Mean time at Greenwich 13h. 00m. 00s., the observed altitude of the sun's L.L. was 46° 17′, and again P.M. on the same day, when the same chronometer (corrected) indicated 16h. 24m. 15s., the observed altitude of the sun's L.L. was 41° 38′, the height of eye at each observation being 29 feet. The ship having made 36 miles on a 232° course during the interval between the observations, required the ship's position when the second altitude was observed.

Sun and Star.

(4) On 4th August, 1929, in latitude by account 42° 30′ S., longitude by account 144° 10′ E., when a chronometer (corrected) indicated Mean time at Greenwich 05h. 59m. 19s., the observed altitude of the sun's L.L. was 13° 12′, and again later on the same day, when the same chronometer (corrected) indicated 10h. 28m. 08s., the observed altitude of the star α *Ophiuchi* was 34° 29′ East of the meridian, index error 30″ to subtract, and height of eye 35 feet at each observation. The ship having made 40 miles on a 276° course during the interval between the observations, required the position of the ship when the second altitude was observed, using the Marcq St. Hilaire method by projection.

Simultaneous Altitudes of Altair and Arcturus.

(5) On 14th April, 1929, in latitude by account 50° 30′ N., longitude by account 42° 30′ W., when a chronometer (corrected) indicated 06h. 18m. 10s. Mean time at Greenwich, the observed altitude of the star Altair East of the meridian was 35° 48′; at the same time the observed altitude of the star Arcturus West of the meridian was 45° 06′; height of eye 40 feet, and index error 2′ 30″ to subtract at each observation. Required the ship's position, using the Marcq St. Hilaire method by projection.

Two Altitudes of Procyon.

(6) On 19th March, 1929, in latitude by account 51° 30′ N., longitude by account 160° 12′ W., when a chronometer (corrected) indicated Mean time at Greenwich (20th March) 05h. 10m. 47s., the observed altitude of the star *α Canis Minoris* (Procyon) East of the meridian was 40° 53′, again later on the same day, when the same chronometer (corrected) indicated 09h. 10m. 40s., the observed altitude of Procyon after passing the meridian was 33° 49′, height of eye 36 feet at both observations. The ship having made 42 miles on a 225° course during the interval between the observations, required the ship's position at the time of taking the second observation.

Altitudes of Rigel and Spica.

(7) On 2nd January, 1929, in latitude by account 50° N., longitude by account 180° E., when a chronometer (corrected) indicated Mean time at Greenwich 11h. 57m. 24s., the observed altitude of the star *β Orionis* (Rigel) West of the meridian was 28° 04′, height of eye 35 feet, index error 2′ 30″ to add, and again on the next morning, when the same chronometer (corrected) indicated (2nd January) 16h. 27m. 41s., the observed altitude of *α Virginis* (Spica) East of the meridian was 22° 56′ height of eye 34 feet, index error 1′ 40″ to add. The ship having made 40 miles on a 216° course during the interval between the observations, required the position of the ship at the time of taking the second observation.

NOTES.

Questions and Answers relating to Stars and Planets.

Ques.—Describe where tables may be found which give the times at which the principal stars cross the meridian.

Ans.—The apparent time at which the principal stars cross the meridian may be found in a table commencing on page 584 of the 1924 edition of Norie's Tables. It is given for the first and every succeeding fifth day of each month. The time of the meridian passage on any intermediate day may be found by interpolation.

Ques.—Describe where the time of the meridian passage of the principal planets may be found.

Ans.—The mean time of the meridian passage of Venus, Mars, Jupiter, and Saturn across the meridian of Greenwich is given in the *Nautical Almanac* on pages xi and xii of every month. These times would also be within a few minutes of the correct time in any other longitude.

Ques.—Can the approximate meridian passage of a planet, also its approximate meridian altitude, be found in the same way as in the case of a star ?

Ans.—Yes. The approximate meridian passage can be found by subtracting the sun's R.A. from the planet's R.A. The approximate meridian altitude can also be found by means of the planet's declination and the latitude by account.

Describe any maps or diagrams with which you are acquainted for facilitating the recognition of the stars and planets.

In answering this question you should describe the one you know best. The following answer is only given to show the kind of answer expected :—

" Brown's Star Atlas," showing all the principal bright stars, gives maps of the heavens with all the bright stars and constellations named ; also additional maps of the principal constellations. Directions are also given for comparing the maps with the stars in the sky, and for ascertaining when they are available for observation.

As the planets are constantly changing their position, they cannot be shown on maps the same as the stars, but by looking up their R.A. and Declination from the *Almanac*, and finding this point on the maps of the heavens, the position of any planet at any given time may be seen, and then by noticing its position with respect to neighbouring bright stars it can be traced in the sky. The planets do not twinkle as the stars do, but shine steadily.

LAWS OF STORMS.

The following concise Rules for Revolving Storms are issued by the Hydrographic Department.

1. Revolving storms are so named, because the wind in these storms revolves round an area of low pressure situated in the centre. They have also local names, and are termed Hurricanes in the West Indies and South Pacific Ocean; Cyclones in the Indian Ocean, Bay of Bengal, and Arabian Sea; and Typhoons in the China Sea.

2. In these storms the wind always revolves the same way in the same part of the world—that is, against the movements of the hands of a watch in the Northern hemisphere, and with the hands of a watch in the Southern hemisphere. The wind does not revolve in circles, but has a spiral movement, inwards, towards the centre.

3. Revolving storms have also, as a general rule, a progressive movement. Within the tropics they usually move from East to West at first, and then curve towards the pole of the hemisphere in which the storm is generated, and afterwards move from West to East.

4. The track which the centre of the storm takes is called the path of the storm, and the portion of the storm-field on the right of the path is known as the right-hand semicircle, and that on the left as the left-hand semicircle of the storm.

5. In the right-hand semicircle, if the observer be stationary, the wind will always shift to the right, and in the left-hand semicircle to the left. This law holds good in both hemispheres.

6. If a vessel be so situated in a storm that by running before the wind the path of the advancing storm will be crossed, this is considered to be the dangerous semicircle. This will always be the right-hand semicircle in the Northern hemisphere, and the left-hand in the Southern.

7. These storms are most frequent in the Northern hemisphere from July to November, and in the Southern hemisphere from December to May. In the Bay of Bengal and Arabian Sea, they, however, occur most frequently about the time of the change of the monsoon.

8. The area over which revolving storms have been known to extend varies in diameter from 20 miles to some hundreds of miles, and their rate of movement in the West Indies averages about 300 miles a day; in the China Sea, Bay of Bengal, and Arabian Sea about 200 miles a day; and in the Indian Ocean from 50 to 200 miles a day, the more stationary storms occurring at the beginning and end of the hurricane season.

9. The indications of the approach of a revolving storm are (1) an unsteady barometer, or even a cessation in the diurnal range, which is constant in settled weather; (2) a heavy swell not caused by the wind then blowing; (3) an ugly, threatening appearance of the sky.

10. In order to judge what is the best way to act if there is reason to believe a storm is approaching, the seaman requires to know (*a*) in which direction the centre of the storm is situated; (*b*) in which semicircle the ship is situated.

11. As these points cannot be determined if a vessel is moving with any speed through the water, the first proceeding should be to "stop" or "heave to," and, as it is always best to assume, at first, that the vessel may be in the dangerous semicircle, she should be hove to on the starboard tack in the Northern Hemisphere and on the port tack in the Southern.

12. If an observer faces the wind the centre of the storm will be from 12 to 8 points on his right-hand in the Northern hemisphere, and on his left-hand in the Southern hemisphere ; 12 points when the storm begins ; about 10 points when the barometer has fallen three-tenths of an inch, and about 8 points when it has fallen six-tenths of an inch or upwards.

13. If the wind shifts to the RIGHT the vessel is in the RIGHT-HAND semicircle, if to the LEFT in the LEFT-HAND semicircle, and, if the wind is steady in direction but increasing in force, she is in the direct path of the storm.

14. If the seaman has reason to think that his vessel is in the direct path of the storm, he should run with the wind on the starboard quarter in the Northern and on the port quarter in the Southern hemisphere until the barometer has ceased falling. If she is in the right-hand semicircle in the Northern hemisphere she should remain hove to on the starboard tack, but if in the Southern hemisphere run with the wind on the port quarter ; if she is in the left-hand semicircle in the Northern hemisphere she should run with the wind on the starboard quarter, but if in the Southern hemisphere remain hove to on the port tack.

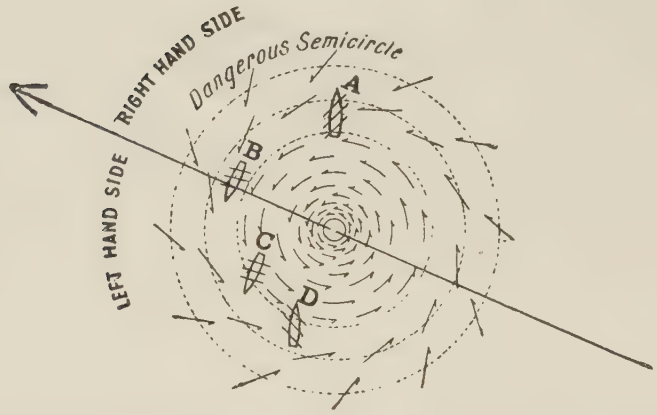
15. Should a vessel not have sufficient room to run when in the least dangerous semicircle, she should heave to on the port tack in the Northern and on the starboard tack in the Southern hemisphere.

16. If in a harbour or at anchor the seaman should be just as careful in watching the shifting of the wind and ascertaining the direction of the centre, as by so doing he will be able to tell on which side of the path of the storm he is situated and be able to act according to circumstances.

17. Should the centre of a storm pass over a vessel, the wind, after blowing furiously in one direction, ceases for a time, and then blows with equal fury from the opposite direction. This makes a confused pyramidal sea, which is especially dangerous.

DIAGRAMS OF CYCLONES.

NORTHERN HEMISPHERE.

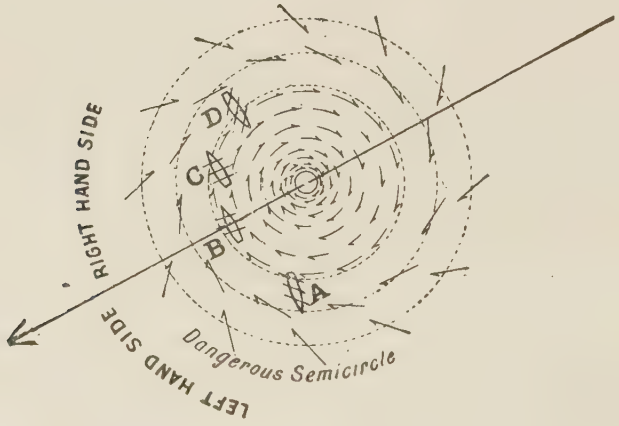


A represents a vessel in the dangerous semicircle hove to on the starboard tack. As the cyclone passed over the ship the wind would veer towards the stern and she would come up and not be likely to get caught aback.

B is a vessel on the line of progression, and *C* represents one in the less dangerous cemicircle. They are running with the wind on the starboard quarter in order to get as far as possible from the centre.

D shows what must be done in the less dangerous semicircle when owing to the nearness of land or any other cause it is not advisable to run. By heaving to on the port tack the wind would back towards the stern as the storm progressed.

SOUTHERN HEMISPHERE.



A is a vessel in the dangerous semicircle hove to on port tack.

B is a vessel on the line of progression, and *C* another vessel in the less dangerous semicircle, both running with the wind on the port quarter.

D is a vessel hove to on the starboard tack in the less dangerous semicircle. This shows what should be done if not able to run.

The causes and effects of the Trade Winds, Monsoons, etc.

If all parts of the globe had the same temperature, the atmosphere pressure would be practically uniform all over the world, the result would be calm, fine weather. Such is not the case however, and those parts that come more directly beneath the sun's rays—*i.e.*, the tropics—have a much higher temperature than the temperate zones, where the sun shines more obliquely on the earth's surface. The atmosphere, being composed mainly of nitrogen, oxygen, and water vapour, is very elastic, and in common with other gases expands when heated and contracts when cooled. It expands or contracts in the same ratio as the Absolute temperature.

From this we have two effects, the air at the equator expands, whilst the air in the colder regions contracts. This upsets the equilibrium of the atmosphere, with the result that between 20° N. and 20° S. we have a low pressure, between latitudes 20° and 40° N. and S. we have a comparatively high pressure, whilst from latitude 40° the pressure decreases towards the poles in both hemispheres. The air in the tropics rises at the same time that it expands, and in consequence of this the upper strata of air moves from the equator towards the poles, whilst the lower strata, at the earth's surface, moves from about Lat. 30°, where the pressure is greatest, towards the equator. A current of air in moving from Lat. 30° to the equator would be meeting the earth where it is rotating at a greater speed, and, therefore, these winds have North-easterly and South-easterly directions. They are indicated in Plates 151 and 152 by the **blue** and **red** colouring, and constitute the N.E. and S.E. trade winds. From these plates we see that they blow in all the oceans with the exception of the Indian Ocean, north of the equator, where they are substituted by the Monsoons.

The general tendency of the atmosphere is to move from localities of high pressure to those of lower pressure, but in doing this they are influenced by the different speeds in the rotation of the earth's surface. In the N. hemisphere currents of air are always deflected to the right, and in the S. hemisphere to the left. Given a high pressure at any particular place, the air moving outwards and turning to the right in the N. hemisphere sets up a circular motion, **with the hands of a watch.** In the S. hemisphere, being deflected to the left, its circular motion would be **against the hands of a watch.** This system of wind is called **Anticyclonic.** If now on Plates 151 and 152 we take Lat. 30° N. and S. to be the high pressure, we find that the wind is acting in conformity with the above. To the eastward of these areas of high pressure we have the N.E. and S.E. trades, and to the northward and southward of Lat. 30° we have westerly winds.

These winds are consistent in all the oceans with the exception of the Indian Ocean, where the great continent of Asia so closely approaches the equatorial region as to upset the system. When the sun is north, the land directly under the sun's rays in northern India gets much hotter than the sea at the equator. The mean barometric pressure in this locality falls to about 1,000 millibars—*i.e.*, about 11 millibars lower than the mean equatorial pressure. The wind, instead of blowing **towards** the equator, now blows **from** the equator, and with considerable violence, this is known as the S.W. monsoon, shown on Plate 152.

When the sun is south there is a high pressure over Asia in about Lat. 30°, and well to the eastward of that continent. This sets up an anticyclonic system similar to that in the Atlantic and Pacific, but the high pressure being exceptionally high and to the eastward we get very strong N.E. winds in the China Sea and moderate winds in the Indian Ocean.

The sun being south at the same time creates a low pressure area in about Lat. 10° to 15° S., which is also affected by the northern part of Australia, where the low pressure area extends still further south. The N.E. monsoon, as this wind is called, blows, therefore, right across the equator to about 10° S. On crossing the equator, however, it is deflected to the left, as all winds are, so that it blows from the N.W., and is now called the N.W. monsoon (*see* Plate 151).

The approximate limits of the trade winds are as follows :—

North Atlantic, ...	6° N. to 28° N.
South Atlantic, ...	2½° N. to 27° S.
North Pacific, ...	10° N. to 27° N.
South Pacific, ...	6° N. to 27° S.
South Indian Ocean, .	January, 15° S. to 30° S. ; July, 0° S. to 25° S.

In the Atlantic and Pacific these limits move slightly with the sun, the polar limits about 5° and the equatorial limits about 3°, the above latitudes being taken as the mean.

Between the N.E. and S.E. trades we have an area of light variable winds and calms, with heavy rain squalls. These are called the **doldrums**, and are shown in both Plates 151 and 152. They are very similar in the Atlantic and the Pacific, and fairly consistent in both oceans. In the Indian Ocean they are both irregular and inconsistent on account of the Monsoons ; there is generally, however, an area of variable winds between the S.E. trades and the N.W. monsoon in about Lat. 10° S., and a similar area between the S.E. trade and the S.W. monsoon in about Lat. 2° S.

The student is advised to study carefully these two plates, 151 and 152, which have been reproduced from the "*Admiralty Manual of Navigation*," by kind permission of the **Controller of His Majesty's Stationery Office.**

METEOROLOGY.

Candidates for mates' and masters' certificates are required to give written answers to a few printed questions on general meteorology.

The " laws of storms " have been discontinued as a separate subject, the meteorology paper being substituted for them. Questions relating to the laws of storms are, however, frequently given in the meteorology papers.

The books to study on the subject are :—

" A Barometer Manual for the Use of Seaman," . . Price 1s. 6d.
" The Seaman's Handbook of Meteorology," . . Price 3s. 6d.

Both are published by the authority of the Meteorological Committee, and may be obtained from any nautical bookseller.

Most of the questions in the following meteorology papers have been given at the examinations, the others are ones which are likely to be given. They will provide candidates with some idea of what is to be expected.

Meteorology Paper I.

1. Give a description of the atmosphere and its composition.

Ans.—The atmosphere is a layer of air completely surrounding our globe and partaking of its rotatory motion.

It is essentially a mixture of oxygen and nitrogen gases, its average composition by volume being :—

Nitrogen, ...	77·11 per cent.
Oxygen, ...	20·65 ,,
Aqueous vapour, ...	1·40 ,,
Argon, ...	0·79 ,,
Carbonic acid, ...	0·04 ,,

2. What is the height of the atmosphere ?

Ans.—The actual height of the atmosphere is not yet known, but it is considered to be at least 100 miles high, and that in an extremely attenuated form, it even reaches to an altitude of 500 miles.

3. Where is the density of the atmosphere greatest ? State how it varies at different altitudes.

Ans.—The atmosphere is densest near the surface of the earth, and its density diminishes as the altitude increases.

Seven miles above the surface of the earth it has one-quarter the density it has at the surface, at fourteen miles one-sixteenth of that density, and at twenty-one miles only one sixty-fourth of that density.

4. **State if there is more moisture in the air during the summer or the winter. Give the reason.**

Ans.—There is more moisture in the air during the summer than there is during the winter.

The amount of moisture or water vapour which dry air is able to hold in suspension increases with the temperature.

As the air temperature is higher in the summer it consequently holds more moisture than it does in the winter when the temperature is lower. The relative amount is indicated by a hygrometer.

5. **Describe the construction and use of a hygrometer.**

Ans.—It consists of a pair of good thermometers placed side by side. Over the bulb of one of these instruments a single thickness of cambric or fine muslin is secured. This covering is kept damp by means of a few strands of cotton wick, the bight of which is hitched round it, while the ends are immersed in pure distilled water contained in a small receptacle placed near the bulb but not under it. This is called the wet bulb thermometer, the one without the covering is called the dry bulb thermometer.

It is usual to keep them in a specially constructed screen, called a Stevenson screen, which keeps them freely exposed to the air but protects them from sun and rain. It is also essential that they should be protected from the effects of radiation.

There should be a space of at least 3 inches between the bulbs of the thermometers and the top, bottom, or sides of the screen.

The principle of its working is that when evaporation is taking place in the atmosphere—that is, when the atmosphere is not saturated—heat will be drawn from the mercury of the wet bulb to evaporate the moisture on it. This will cause it to read lower than the "dry bulb." When the air is saturated, as in rainy, misty, or foggy weather, no evaporation takes place, and under these conditions the "wet bulb" and the "dry bulb" have the same readings.

The difference between the wet bulb and the dry bulb readings gives us the proportion that the air is short of being saturated. It averages about 15° in England, but seldom more than 10° at sea.

6. **What is the cause of *rain*?**

Ans.—Rain is caused by a diminution of the temperature of the air below the point of saturation. When the minute spherical drops of water of which cloud is composed become larger and heavier by the condensation of aqueous vapour and unite, they fall as rain.

7. **Describe *cirrus* clouds.**

Ans.—These are detached clouds of delicate or fibrous appearance often showing a feather-like structure, generally of a white colour. They take the most varied shapes, such as isolated tufts, thin filaments on a blue sky, threads spreading out in the form of feathers, curved filaments ending in tufts, etc. They are high clouds, their altitude varying from 4½ to 6¾ miles. Seamen often give them the name of *mare's tails*, and as such they may be easily recognised. They are composed largely of ice crystals.

Miscellaneous Paper II

1. **How can you tell by means of the hygrometer whether the air contains much or little moisture?**

Ans.—By comparing the readings of the two thermometers. If they both show the same temperature the air is completely saturated. A large difference between the readings indicates a dry atmosphere.

2. **What is the largest difference between the readings which is likely to be found? Is it generally greater inland or near the sea?**

Ans.—The difference may amount to as much as 20° in the British Islands, and to more than 20° in some parts of the world.

The difference is generally greater inland than it is near the sea.

3. **What is meant by "*the point of saturation*"?**

Ans.—That point at which the air contains the greatest possible quantity of water vapour or moisture. It depends on the temperature. The amount of moisture which dry air is able to hold in suspension increases with the temperature.

4. **What is meant by *latent heat*?**

Ans.—Latent heat is heat which is hidden and is not perceptible. When a liquid is in process of conversion to a gaseous form a large measure of its heat becomes absorbed, and therefore latent. Although the heat thus absorbed cannot be detected by the aid of a thermometer, and is imperceptible to the senses, it is not lost, but hidden, and will re-appear when the vapour is restored to the liquid state.

As the conversion of water into vapour by the process of evaporation is attended with a decrease of temperature due to the absorption of heat, so the conversion of vapour into the liquid state is attended with an increase of temperature due to the release of latent heat.

When air is expanding under pressure, the heat causing the expansion is hidden and is said to be *latent*.

That is one reason why the air at a high altitude is colder than air near the earth. As it rises it is subjected to less pressure, it therefore expands and becomes colder on account of its heat becoming latent.

5. **What causes the formation of dew?**

Ans.—The cooling of the air, by radiation, below the temperature of the dew point—that is, to the temperature necessary to cause condensation of the aqueous vapour in the air. When that happens, the vapour in the air is condensed and deposited on the surface of the earth and on other objects in the form of minute drops of water, which are called dew.

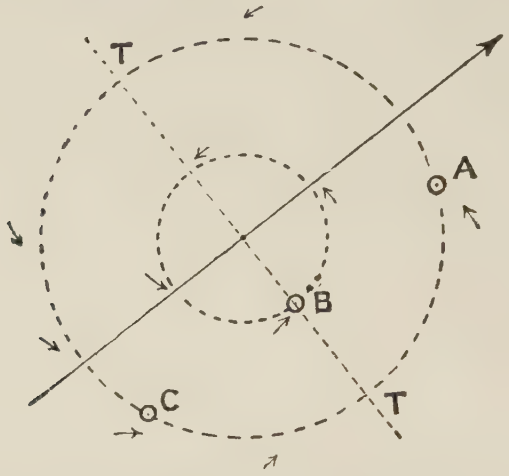
6. **What is hoar frost?**

Ans.—Frozen dew. When an object loses so much of its heat that its temperature falls below 32° F., the drops of water deposited on it, which under warmer conditions would remain as dew, become frozen and are called hoar frost.

7. **Give a description of cumulus clouds.**

Ans.—Cumulus clouds are thick clouds of which the upper surface is more domed or consisting of masses or rounded heaps, while the base is horizontal. True cumulus has well defined upper and lower limits. The upper part sometimes resembles cauliflowers in appearance. When cumulus takes the form of long rolls it is called roll cumulus. The base of cumulus is generally about ½ mile to 1½ miles high.

8. Southward of the line of progression of a cyclone passing over the British Isles, what sequence of weather would probably be experienced?



Ans.—At the commencement the wind would be about S. to S.E., as shown by *A* in the figure. As the storm proceeded on its path the observer would find himself at *B*, where the barometer would be at its lowest reading, he then being in the trough of the storm. The trough of the storm is indicated by *T T*. The wind by this time would have hauled round in a south-westerly direction. Eventually, as the storm proceeded still farther on its track, he would find himself at *C* when the main part of the storm would have passed him; the wind then being westerly or north-westerly.

At *A* the sky would probably be lined with cirrus clouds, or strata cumulus with cirrus above, the wind would be freshening with heavy squalls, the sea being generally confused by a swell not caused by the wind then blowing.

At *B* the observer would be in the full blast of the storm and very near to its centre, the sky would be overcast with nimbus, fracto nimbus (scud), strata cumulus or alto stratus; very heavy squalls would be experienced, with or without rain, often with a great deal of thunder and lightning. The sea would be high and dangerous.

At *C* the sky would commence to show signs of clearing up, patches of blue appearing between the clouds, the squalls becoming less frequent and less violent as the storm has done its worst and passed away to the north-eastward.

METEOROLOGY PAPER III.

1. Give a description of cirro-cumulus clouds.

Ans.—Cirro-cumulus clouds generally appear as small globular masses or white flakes without shadows or showing very light shadows, arranged in groups and often in lines. Cirro-cumulus clouds, when they occupy a large area give the dappled appearance popularly described as a *mackerel sky*. They have a fairly constant height of $4\frac{1}{2}$ to 5 miles.

2. Describe *cirro-stratus* clouds.

Ans.—Cirro-stratus are high clouds, occasionally they have been observed at a greater height than cirrus; but, on the whole, they are somewhat lower, having an altitude of 4 to $5\frac{1}{2}$ miles. They take the form of a thin whitish cloud sometimes covering the sky completely and giving it only a milky appearance. It is then called *cirro-nebula*. At other times it presents, more or less distinctly, a formation like a tangled web.

Cirro-stratus has jointly the characteristics of cirrus and stratus, and claims special notice as a herald of atmospheric disturbance.

3. What are *nimbus?*

Ans.—A thick layer of dark clouds, without shape and with ragged edges from which steady rain or snow usually falls.

4. What is meant by the term "dry air." What is the weight of a cubic foot of dry air at sea level?

Ans.—Dry air is air which does not contain any aqueous vapour (water vapour), and is represented by O on the scale of relative humidity. It is not possible to get a perfectly dry air under natural conditions, as the air at all times contains a small amount of aqueous vapour. The weight of a cubic foot of practically dry air at sea level is about 500 grains.

5. By what process does the atmosphere receive its moisture?

Ans.—By the process of evaporation which takes place from the surface of the sea, from other water on the earth's surface, also ice, snow, and other moist surfaces. Minute particles of water rise in the form of vapour and float in the air between the molecules of the two gases, nitrogen and oxygen. The warmer the air the larger the quantity of moisture it can sustain in an invisible state.

6. Describe radiation, what retards and what accelerates it?

Ans.—The surface of the earth acquires its heat from the sun, but in heating the earth the sun's rays pass through the atmosphere with but little resistance, and do not, consequently, increase the temperature of the atmosphere to the same extent as that of the earth. The effect of this is that the earth becomes much hotter than the air above it, and that heat flows from the earth to the atmosphere, a process known as radiation.

The more heat that is lost by the earth the colder it becomes. In cloudy weather the ascending currents of warm air are arrested by the clouds, and this retards radiation. In calm, cloudless weather the ascending currents of warm air are not obstructed in any way, so that radiation is accelerated.

7. What portion of an iceberg is visible above water, and why?

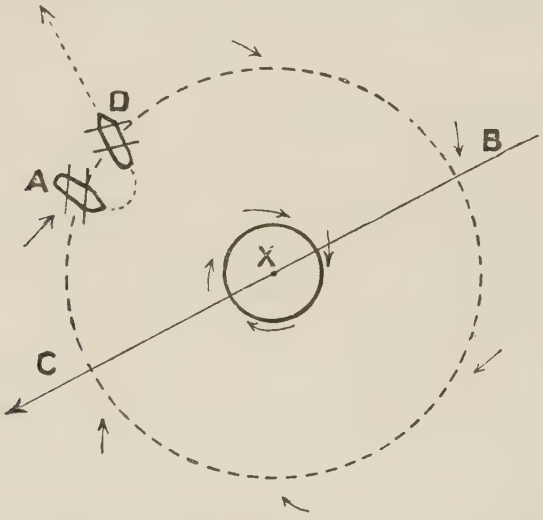
Ans.—Water expands 10 per cent. of its volume when frozen. Ice is, therefore, 10 per cent. lighter than water, volume for volume. From this we see that when ice is placed in water $\frac{9}{10}$ of its volume will be submerged, leaving $\frac{1}{10}$ above the surface of the water. This, of course, refers to pure ice. Icebergs are generally composed of ice and other matter, such as pieces of rock, etc., adhering to their sides. Air pockets in the berg would cause it to float higher out of the water, so that we get results of about $\frac{1}{7}$ to $\frac{1}{9}$ of the volume above water. Some icebergs are so heavily weighted with foreign matter that they eventually sink altogether, due to the melting of the ice and to the weight of rock, earth, etc., clinging to them or embedded in them.

METEOROLOGY PAPER IV.

1. **Describe the cyclones of the Indian Ocean, giving their tracks and seasons.**

Ans.—The cyclones of the Indian Ocean originate in about latitude 10° to 12° S., travelling in a W.S.W. direction until they reach about latitude 21° S., where they recurve to the Southward and South-eastward. Their rate of progression is generally less than that of storms in the other oceans, it averaging somewhere about 140 miles per day. The slower moving storms occur at the beginning and towards the end of the season. They occur between the months of November and May, being most frequent in January and March.

2. **A steamer with the wind on the starboard beam is in the right-hand semicircle of a cyclone in the Southern hemisphere. State if any alteration of course is necessary, and if so, for what reason.**



Ans.—A steamer carrying the wind on the starboard beam would be heading towards the centre of the storm, as indicated by the vessel in position *A* in the diagram. The dotted circle represents the storm, the arrowheads indicate the direction of the wind, X the storm's centre, and *B X C* the direction in which it is travelling. An alteration of course would be necessary. The steamer should be run off, and the wind brought round the stern on to the port quarter. She would then be heading away from the centre of the storm, as shown at position *D*. By making as much speed as possible under the circumstances she would be increasing her distance from the centre, that being the reason for which the course should be altered.

3. **Explain circumstances that give rise to fog at sea.**

Ans.—Fog is generally caused by the air immediately above the earth being cooled below the point of saturation, the aqueous vapour in an invisible form being turned into visible particles of water so closely assembled as to obstruct the vision. It is cloud at the earth's surface.

The formation of sea fog is due principally to the effect of a warm moist wind passing over relatively cold water; and, less frequently, to that of a cold wind passing over warm water.

A warm, humid wind passing over water of a lower temperature is cooled, and the excess of vapour, after the point of saturation has been reached, may be condensed and become visible as mist or fog.

In like manner, a cold wind passing over water of a considerably higher temperature than its own, chills below the point of saturation the vapour as it rises, when it becomes visible as mist or fog.

The lower the temperature of the air the less aqueous vapour can it hold in an invisible state.

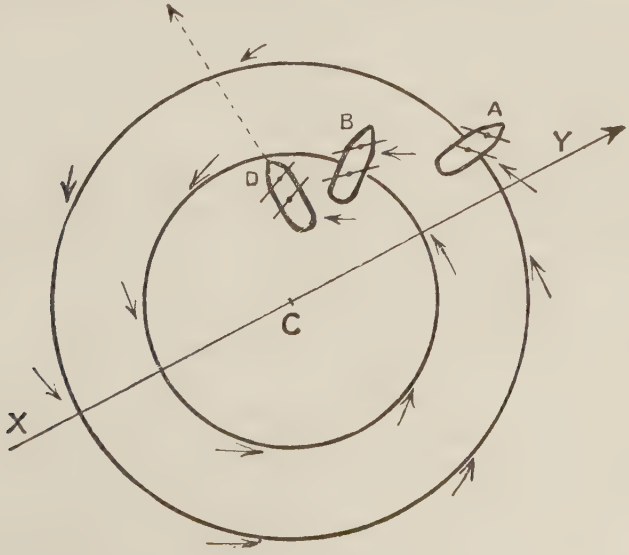
4. At what times will there be the mean barometrical pressure in the tropics, and for what reason?

Ans.—The barometer readings in the tropics are more affected by temperature than they are in the temperate zones. The result of this is that a regular daily range of the readings is experienced which reaches its highest point at 10 A.M. and 10 P.M. and its lowest point at 4 A.M. and 4 P.M. This is called the diurnal range, and the difference between the lowest and highest readings from this cause is about 2·4 millibars. The time to read the mean barometrical pressure would be between the highest and lowest readings—*i.e.*, at 1.0 o'clock and 7.0 o'clock A.M. and P.M.

5. Your ship is hove to in the Northern hemisphere with a cyclone approaching. The wind shifts to the left. What would you do, and for what reason?

Ans.—The wind shifting to the left indicates that the vessel is in the left-hand semi-circle of the storm. This being the least dangerous one in the Northern hemisphere, I should put my helm up, and run with the wind on the starboard quarter. The object in doing this is to increase my distance from the centre, which is the most dangerous part of it. As I got further away, the barometer would rise, the squalls would moderate and occur at longer intervals, and there would be a general clearing up of the weather. I should then either shape my course again or heave to on the port tack until the storm had finally passed away.

In the diagram, *C* represents the centre of the storm, *X Y* its path, the arrows indicating the direction of the wind. *A* the first position of the vessel hove to on the starboard tack. *B* her position when the storm has advanced and the wind shifted. *D* shows her running with the wind on the starboard quarter, and increasing her distance from the centre.



6. With equal gradient in U.K. and the tropics, where would you expect the strongest wind?

Ans.—The wind would be stronger in the tropics than in the U.K. for the following reasons :—(1) There is more swirl given to the wind on account of the earth's surface revolving at a much greater speed in the tropics than in higher latitudes, and (2) the weight of the air is heavier in high latitudes on account of the gravitation of the earth being greatest at the poles and least at the equator. The friction of the wind with the earth's surface would be greater in high latitudes on account of this, thus retarding the velocity of the wind.

7. Why is the range of temperature less in the U.K. than on the continent?

Ans.—In all countries that are surrounded or nearly surrounded by the sea their climates are more equable than those that do not come under the influence of the oceans.

The cause of this is that land is more susceptible to heat than water, it gets warm more quickly and conversely, it gets cold more quickly, not having the same power of retaining its heat that water has. The result of this is that in winter the surrounding sea is warmer than the land whilst in summer the sea is cooler than the land ; in the first case the sea prevents the land from becoming intensely cold and in the summer it keeps it from becoming intensely hot.

In addition to this, the British Isles are under the influence of the Gulf Stream, which flows from the tropics to the coasts of Britain. This current being warm at all times, it prevents the climate of the U.K. from reaching the extreme cold suffered by other countries in the same latitude.

Meteorology Paper V.

1. How is hail formed, and when is it most frequent in the U.K.?

Ans.—The globules of ice which fall in the atmosphere are called hail. They vary in size from the size of a small shot to an egg. The real hail is hard and compact, which is distinct from the soft variety, the latter consisting of light grains of snow-like substance. Soft hail seldom falls in the summer, but frequently in winter.

True hail stones have a core of compressed snow which is encased in layers of ice.

All hail is probably connected with cyclonic storms more or less developed. At or near the centre of these storms the wind ascends and carries any rain-drops that are formed below up with it. On reaching the upper regions these become frozen, and if thrown clear of the system would descend as blocks of clear ice. If taken higher up they would become coated with snow, and fall as snow-covered ice.

Often these particles of frozen rain-drops fall within the limits of the storm, and are again carried up with the rising currents of air, this process being repeated until they are eventually thrown clear of the system altogether, when they fall to the earth as hail. In Europe hailstorms occur most frequently during late Spring and in Summer months, commonly between 11 A.M. and 5 P.M.

2. Describe field ice, its formation and colour.

Ans.—Field ice, which is flat ice, often occupying a large area and rendering it unnavigable, is formed near the shore, and, when in motion, being more under the influence of wind than of current, it often piles, thus becoming uneven.

Fragments of bergs or growlers as they are termed, which at times become trapped and embedded in field ice, are an additional menace to shipping, although they can, as a rule, be detected at some distance in consequence of their dark-blue colour.

3. What is *snow?* State anything you know about it.

Ans.—Below some temperature, at present unknown, the excess of aqueous vapour in the atmosphere condenses on dust particles in the air in the form of ice crystals, and falls as snow.

Viewed under the microscope, snow crystals exhibit stellate structures of great delicacy and beauty, especially when formed in a calm atmosphere. They take the form of a six-pointed star. More than a thousand various modifications of these crystals have been observed, but as a rule those that fall in a locality at the same time are alike.

A foot of snow is equivalent to about an inch of rain. Snow is measured by thawing what is collected in the rain gauge and measuring the resulting water; or by melting the snow by adding a known quantity of hot water, which quantity is deducted.

4. Where are the sun's rays hottest, and for what reason?

Ans.—The sun's rays are hottest within the tropics. The reason for this is that in these regions the sun is in a position more perpendicular to the earth than it is to any position outside the tropics. The sun is truly perpendicular to one part of the tropics or another at all times. The heat of his rays increase with his altitude.

5. Describe alto-stratus clouds.

Ans.—These clouds generally appear as a thick sheet of a grey or bluish colour, which forms a fairly compact mass. At other times the sheet is thin, somewhat resembling cirro-stratus, and through which the sun or moon may be seen dimly as if shining through frosted glass. It is through these clouds that we see coronæ around the sun and moon. They are usually from two to three miles in height.

6. What is *Buys Ballot's law*, and where did it get its name from?

Ans.—Buys Ballot's Law may be enunciated as follows:—

In the Northern Hemisphere, stand with your face to the wind, and the barometer will be lower on your *right* hand than on your left.

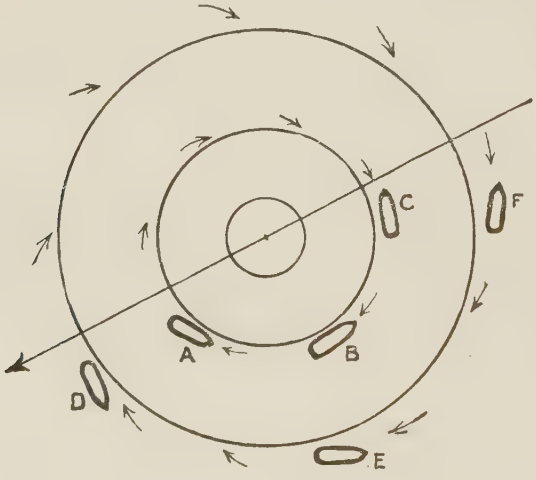
In the Southern Hemisphere, stand with your face to the wind, and the barometer will be lower on your *left* hand than on your right.

It is known as Buys Ballot's Law, because the principle it demonstrates was first publicly announced in Europe by Professor Buys Ballot, of Utrecht.

7. In the left-hand semicircle of a Southern hemisphere cyclone, a vessel is kept steaming slowly head to wind. Describe the changes of weather that would be experienced.

Ans.—The ship is in the dangerous semicircle of the storm. She would probably make little headway against the wind, in which case the centre of the storm would pass dangerously near to her if not actually over her. See positions *A* and *D* in diagram. If she was able to make good headway, by keeping head to wind she would be constantly altering her course to port, and would steam practically round the centre of the storm without increasing her distance from it. If at *A* in the first case she would be in positions *B* and *C* as the storm progressed. If at *D* in the first case she would be in position *E* and *F* later on. In the latter case the centre of the storm would pass to the Northward of her. In both these cases she would experience fierce squalls and a confused and dangerous sea, but not much change in the weather until the centre had passed, when conditions would gradually improve.

If at *A* or *D*, and unable to make headway, the weather would get worse, the squalls becoming fiercer and occurring at shorter intervals as the centre approached, the sky would be densely overcast with principally nimbus clouds, the sea would be very confused and dangerous, and the barometer would continue to fall. Should the centre pass over the ship, she would probably lose the wind until the centre had passed by, when it would blow with equal force from the opposite direction. She would then be in the rear part of the storm, which would be receding from her. The barometer would rise, the wind and squalls would moderate, and the weather would gradually improve as the storm finally passed away.



Meteorology Paper VI.

1. What is a solar halo, and how is it formed?

Ans.—A solar halo consists of a number of circles round the sun. When well developed they show prismatic colours the same as the rainbow, the red being next to the sun and the violet farthest away from it. When only of slight intensity they appear white. They are formed by the reflection and refraction of the sun's rays from ice crystals in cirrus and cirro-stratus clouds.

2. What is meant by the terms "veering" and "backing" of the wind?

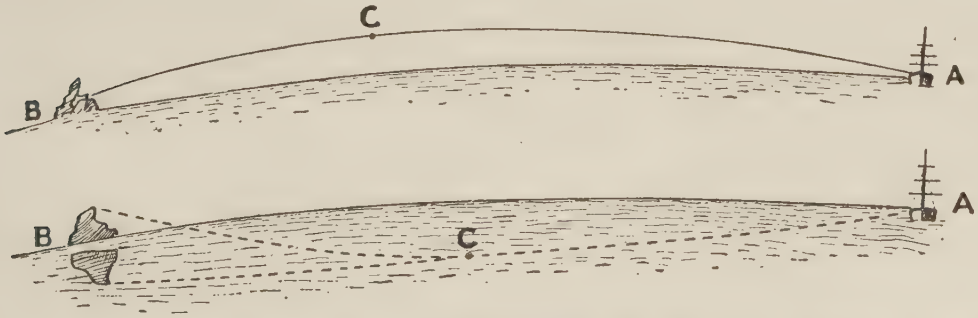
Ans.—The wind is said to be "*veering*" (seamen often say it is "*hauling*") when it changes in the same direction as that followed by the hands of a watch, and to be "*backing*" when it changes in the opposite direction.

These expressions convey the same meaning in both hemispheres.

3. What are the conditions that produce mirage?

Ans.—Abnormal refraction, and reflection. Rays of light when passing through different densities of atmosphere are always refracted towards the horizontal. When there is a large difference between the density of the air at sea level and that of the strata of air immediately above it, the rays of light suffer abnormal refraction and may become nearly horizontal. When this condition is reached, as at *C* in the top drawing, reflection succeeds refraction, rays are bent downwards and again undergo refraction, but in a contrary direction, until they reach the horizon at a distant point. The horizon at this point appears too high, and objects such as *B* that are below the horizon may thus be observed.

These conditions are frequently met with in the tropics, where a layer of air, which has been previously heated over the land drifts across the sea, thus having a layer of air beneath it which is cooled by contact with the water.



Another form of refraction is sometimes met with in temperate climates, where the air in immediate contact with warm currents of the sea, as the Gulf Stream, etc., becomes abnormally warm, and in great contrast to the strata of air above it.

The rays of light in this case are refracted downwards, and on reaching the surface of the sea are again reflected upwards.

In this case the objects on the horizon appear to be upside down and slightly below their real position, as shown in the lower drawing.

4. Is there any change in the temperature of the atmosphere as the altitude increases? If so, state why.

Ans.—Yes. *The temperature of the air decreases with the height* to a great altitude, for as the height increases there is necessarily a loss of warmth derivable from the heated surface of the earth.

The sun heats the earth's surface, very little of it being absorbed in passing through the atmosphere. Those layers, or strata, of air which lie nearest to the earth's surface, therefore, acquire by conduction more heat than those at a greater altitude, and the layer in contact with the earth receives most of all.

Another reason for the decrease of temperature at high altitudes is that air in the higher regions of the atmosphere is subjected to less pressure than obtains at lower altitudes, and while expanding under pressure, the heat required to cause the expansion becomes latent, thus a fall in temperature ensues.

5. Describe briefly the cause of the *N.E. and S.E. trades.*

Ans.—Near the equator the air is warmer than in higher latitudes. It, therefore, expands and rises. Cooler air from the Northward and Southward flows in to take its place. This accounts for the Northerly and Southerly direction.

The earth revolving from West to East makes the wind apparently come from the East. This accounts for the easterly direction.

The result of the combination is the N.E. and S.E. trades.

6. Describe the meaning of the terms *dry air, saturated air, and relative humidity.*

Ans.—Dry air is air which contains little or no moisture, or, in other words, air which has little or no aqueous vapour mixed with it. It is composed principally of nitrogen and oxygen.

Saturated air is air which contains the largest possible quantity of moisture or water vapour which it can hold. The higher the temperature the greater the capacity of the air for moisture.

Referred to a scale of 0 to 100, the latter being assumed to represent saturation, and the former perfectly dry air, the quantity of moisture in the air can be expressed in figures as a percentage of the amount necessary to produce saturation, the temperature remaining the same. This proportion of moisture to saturation is known as relative humidity.

7. You are on the line of progression of a cyclonic depression in the Northern Hemisphere. Describe the conditions of wind and weather you would experience and what action you would take.

Ans.—Cirrus clouds would appear in the direction from which the depression was advancing, and the barometer would fall. The wind would increase and become squally, the sky would become overcast, the cirrus changing into cirro-stratus and later into nimbus, rain setting in. As the centre of the depression got nearer, the barometer would continue to fall, the wind would blow hard and be accompanied with severe squalls, but would not change much in direction.

I should run away into the left-hand or least dangerous semicircle of the storm, and thence out of it altogether. In a sailing ship I should start with the wind on my starboard quarter, hauling her up a little as I increased my distance from the centre of the storm.

If in a steamer, I should follow the same track.

I should then expect to find the weather moderating, the squalls taking off, and occurring at longer intervals, the barometer rising, and sky clearing; when the depression had passed away and normal conditions prevailed, I should shape my course again.

TO CALCULATE FREIGHT AND COMMISSION.

To find the gross freight.—Multiply the number of tons of cargo by the amount of freight per ton, the result is the gross freight.

To find the Commission.—Multiply the gross freight by the rate per cent. of the commission, and divide the product by 100 ; the result is the commission.

To find the net freight.—Deduct the commission from the gross freight, the remainder is the net freight.

Worked Example I.

Find the gross freight on 2,156 tons of cargo at £1 5s. per ton ; also find the net freight after paying commission at 4 per cent.

Number of tons = 2156
Freight per ton × 25 Shillings.

10780
4312
2,0)5390,0 Shillings.

Gross Freight, £2695
Commission, 107 16

Net Freight, £2587 4

Commission.

Gross Freight, . . . £2695
Percentage, . . . 4

107,80
20

s. 16,00

After multiplying by the freight in shillings divide by 20 to bring to pounds.

To divide by 100 in finding the commission, mark off the last two figures, then multiply them by 20 to reduce to shillings, and again mark off the last two figures. If these had not been ciphers they would have been multiplied by 12 to reduce to pence, again cutting off the last two figures.

Worked Example II.

Find the gross freight on 1860 tons at £1 12s. 6d. per ton ; also find the net freight after deducting commission at the rate of $2\frac{1}{2}$ per cent.

Number of tons = 1860
Freight per ton, 32·5 Shillings.

9300
3720
5580
2,0)6045,0·0 Shillings.

Gross Freight, £3022 10 0
Commission, 75 11 3

Net Freight, £2946 18 9

Commission.

£ s.
Gross Freight, . . 3022 10
$2\frac{1}{2}$

× 2 = 6045 00
× ½ = 1511 5

£75,56 5
20

s. 11,25
12

d. 3,00

£1 12s. 6d. = 32·5 shillings, therefore multiply by 32·5.

In multiplying by the percentage of commission, where the half occurs, multiply first by the 2, then take ½ the gross freight, and add it to the product obtained by multiplying by 2.

FOREIGN MONEY.

When the question is given in foreign money, find the gross freight in that money, and turn to English money by dividing by the rate of exchange. Then carry on as in previous examples.

Worked Example III. (Foreign money).

Find the gross freight on 2500 tons at 28·46 francs per ton, also the amount in English money, the rate of exchange being 25·34 francs to the £. Find also the commission at 4 per cent., and thence the net freight.

Number of tons = 2500
Freight per ton, 28·46

15000
10000
20000
5000

Gross freight, 71150·00 francs.

	£	s.	d.
Gross freight in English money	2807	16	3
			4

112,31 5 0
20

6,25
12

3,00

Commission, £112 6s. 3d.

Rate of exchange. Gross freight.

25·34)71150·00(£2807
5068

20470
20272

19800
17738

2062
20

25·34)41240(16s.
2534

15900
15204

696
12

25·34)8352(3d.
7602

Gross freight,	£2807	16	3
Commission,	112	6	3
Net freight,	£2,695	10	0

Worked Example IV. (Foreign money).

Find the gross freight on 2650 tons at 3·85$ per ton, 2430 tons at 5·65$ per ton, and 3520 tons at 3·25$ per ton, the rate of exchange being 4·85$ to the £. Required also, the amount in English money, and after paying a broker commission at the rate of 3 per cent., find the net freight.

When more than one parcel of cargo is given, find the gross freight on each in foreign money, and add them together. Then turn into English money, and finish as in the preceding example.

2650 tons. 3·85$	2430 tons. 5·65$	3520 tons. 3·25$
13250	12150	17600
21200	14580	7040
7950	12150	10560
10202·50$	13729·50$	11440·00$

10202·50$
13729·50$
11440·00$

Gross freight, 35372·00$

Rate of exchange. Gross freight.

4·85)35372·00(£7293
3395

1422
970

4520
4365

1550
1455

95
20

4·85)1900(3s.
1455

445
12

4·85)5340(11d.
5335

	£	s.	d.
Gross freight,	7293	3	11
			3
	218,79	11	9
	20		
	15,91		
	12		
	11,01		
	£	s.	d.
Commission,	218	15	11

	£	s.	d.
Gross freight,	7293	3	11
Commission,	218	15	11
Net freight,	7074	8	0

FREIGHT AND COMMISSION.

Examples for Exercise XVII.

(1) Find the gross freight on 1860 tons of cargo at £1 15s. per ton; also find the net freight after allowing for commission at the rate of 4 per cent.

(2) Find the gross freight on 2318 tons at £1 4s. per ton; also find the net freight, the rate of commission being 3 per cent.

(3) Find the gross and net freight on 1420 tons at £2 per ton, the commission being at the rate of 5 per cent.

(4) Find the gross and net freight on 3275 tons at £1 12s. per ton, the commission being at the rate of 4 per cent.

(5) Find the net freight on 2450 tons at £1 7s. 6d. per ton, commission at the rate of 2 per cent.

(6) Find the net freight on 1900 tons at £1 10s. per ton, the commission being $2\frac{1}{2}$ per cent.

(7) Find the gross freight on 2240 tons coal at 12 rupees per ton, the rate of exchange being 15·5 rupees to the £. You pay a broker commission at the rate of $3\frac{1}{4}$ per cent., find the net freight in English money.

(8) Find the gross freight on 1100 tons cargo at 23·45 marks per ton, and 1280 tons cargo at 25·60 marks per ton. The rate of exchange is 20·55 marks to the £. Commission being paid at the rate of 4 per cent., find the net freight in English money.

(9) Find the gross freight on 1460 tons cargo at 4·65$ per ton, 2225 tons at 7·22$ per ton, and 3643 tons at 5·47$ per ton. Required the amount in English money, the current rate of exchange being 4·85$ to the £. If commission was paid at the rate of $3\frac{1}{2}$ per cent., find also the net freight.

(10) Find the gross freight on 1800 tons cargo at 28 francs per ton. Required also the amount in English money, the current rate of exchange being 25·60 francs to the £. After paying a broker commission at the rate of 5 per cent., find the net freight.

TO FIND THE CAPACITY OF A HOLD OR BUNKER.

RULE.—*Multiply together the length, breadth, and depth of the hold or bunker (expressed in feet), and divide the product by the number of cubic feet to one ton of the cargo or coal to be placed in the hold or bunker.*

WORKED EXAMPLE I.

Find the capacity of a hold or bunker which is 35 feet long, 10 feet in breadth, and 8 feet deep, allowing 40 cubic feet to a ton.

35 Length.
× 10 Breadth.
350
× 8 Depth.
40)2800 Cubic feet.
Ans. 70 Tons.

WORKED EXAMPLE II.

Find the capacity of a hold or bunker 38 feet long by 9 feet broad, and 8 feet deep, allowing 46 cubic feet to a ton.

38 Length.
9 Breadth.
342
8 Depth.
46)2736(59 Tons.
230
436
414
22
20
46)440(9·6 Cwts.
414
260
276

If there is any remainder after finding the tons, multiply it by 20 to reduce to hundredweights (cwts.).

WORKED EXAMPLE III.

A hold is 24 feet wide and 10 feet deep. If you stow 150 tons of cargo against the forward bulkhead, find how far aft it will extend, allowing 45 cubic feet to a ton.

RULE.—Multiply the number of tons by the number of cubic feet per ton, and divide the result by the product of the two given dimensions. The result is the third dimension.

Breadth, ... 24
Depth, ... 10
240
No. of tons, . . . 150
Cubic feet per ton, . . 45
750
600
6750

240)6750(28 feet.
480
1950
1920
30
12
240)360(1·5 inches.
240
1200
1200

Answer, 28 feet 1·5 inches.

Examples for Exercise XVIII.

(1) Find the capacity of a hold which is 28 feet long, 12 feet broad, and 11 feet deep, allowing 42 cubic feet to a ton.

(2) Find the capacity of a hold or bunker which is 42 feet by 11 feet by 8 feet, allowing 42 cubic feet to a ton.

(3) Find the amount of coal a bunker which is 22 feet by 9 feet by 10 feet will hold, allowing 45 cubic feet of coal to a ton.

(4) A hold measures 31 feet by 12 feet by 9 feet. How much cargo will it hold, allowing 43 cubic feet to a ton?

In the following examples calculate how far fore and aft the given quantities of cargo would extend.

	No. of tons.	Breadth of hold.	Depth of hold.	Cubic feet per ton.
5	70	8 feet	10 feet	40
6.	100	15 feet	9 feet	45
7.	150	20 feet	8 feet	36
8.	300	24 feet	11 feet	42

TO FIND THE CUBIC CAPACITY OF A TRIANGULAR TANK.

First find the area of the top or bottom.

If one of its angles is a right angle, multiply the two smallest sides together, and divide the product by 2. The result is the area.

Then area × depth = cubic capacity.

Example I.

Find the cubic capacity of a right-angled tank 6 feet deep, the sides being 11 feet, 8·2 feet, and 7·4 feet.

8·2	log, ...	0·913814
7·4	log, ...	0·869232
	log, ...	1·783046
2	log, ...	0·301030
Log of area,	. . . . .	1·482016
Depth 6 feet, log,	. . . . .	0·778151
Log,	. . . . .	2·260167

Capacity, 182·0 cubic feet.

Example II.

Find the cubic capacity of a tank which is $5\frac{1}{2}$ feet deep, the sides measuring 12 feet, 10 feet, and 4 feet.

First find the area of the top or bottom, as follows :—

Call the three sides a, b, and c, add them together and divide the sum by 2 (call the result "s").

Subtract each side separately from "s," which gives us $(s - a)$ $(s - b)$ $(s - c)$.

Add up the logs of these four quantities, and divide the sum of these logs by 2. The result is the log of the area.

Then, area × depth = cubic capacity.

a	= 12		
b	= 10		
c	= 4		
	2)26		
s	= 13	log	1·113943
$s - a$	= 1	log	0·000000
$s - b$	= 3	log	0·477121
$s - c$	= 9	log	0·954243
		2)	2·545307
Log of area, .		.	1·272653
Depth 5·5 feet, log,			0·740463
		log	2·013016

Capacity, 103·0 cubic feet.

TO FIND THE CUBIC CAPACITY OF A CYLINDER OR CIRCULAR TANK.

Formula :—

Diameter in feet^2 × height in feet × ·7854.

(The easiest way to work this out is by "logs.")

Example.

Find the cubic capacity of a cylinder 8 feet in diameter and 12 feet deep.

Diameter	= 8 feet.		
	8		
Diameter^2	= 64	log	1·806180
Depth	= 12	log	1·079181
	·7854	log	9·895091
		log	2·780452

Capacity, 603·2 cubic feet.

Note that the cubic capacity will be in cubic inches if the measurements are given in inches, but will be in cubic feet if the measurements are given in feet.

6¼ gallons = 1 cubic foot.
36 cubic feet of fresh water = 1 ton.
35 cubic feet of salt water = 1 ton.

To find the number of gallons the above tank will hold, multiply the cubic capacity by 6¼ (6·25).

603·2	log	2·780452
6·25	log	0·795880
	log	3·576332

3770 gallons.

To find the number of tons of *fresh* water the above tank will hold, divide the cubic capacity by 36.

603·2	log	2·780452
36	log	1·556302
	log	1·224150

16·76 tons.

To find the number of tons of salt water the above tank will hold, divide the cubic capacity by 35.

603·2	log	2·780452
35	log	1·544068
	log	1·236384

17·23 tons.

Examples for Exercise XIX.

(1) Find the cubic capacity of a cylinder 8 feet in diameter and 10 feet deep, also the number of gallons it will hold.

(2) Find the cubic capacity of a triangular tank 7 feet deep, one of its angles being a right angle, the three sides measuring 11 feet, 9·1 feet, and 6·2 feet. State also the weight of fresh water it will contain.

(3) Find the cubic capacity of a triangular tank 6 feet deep, the three sides measuring 12 feet, 9 feet, and 7 feet. State also the weight of salt water it will hold.

(4) Find the cubic capacity of a circular tank 7 feet in diameter and 9 feet deep, also its capacity in tons of fresh water.

ON THE USE OF THE HYDROMETER.

To find the draught to which a ship should be loaded in water of any density, in order to have a given draught in sea water.

RULE.—Multiply the density of sea water by the given draught and divide the product by the density of the water the ship is to be loaded in. The average density of sea water is about 1025 or 1026 ounces to the cubic foot. Candidates may have to find the densities of two different samples of water, one representing sea water, the other representing the dock water in which the vessel is to be loaded, and use these densities in their calculation.

Worked Example I.

Find the draught to which a ship must be loaded in a dock where the density of the water is 1006 ozs., in order that she may float at a draught of 20 feet in sea water, the density of which is 1026 ozs.

Density of sea water, . . 1026
Multiply by draught, . . 20 feet
Density of dock water, 1006)20520(20 feet
2012
400
12
1006)4800(4·7 ins.
4024
7760
7042

Ans.—Ship must be loaded so as to draw 20 feet 4·7 inches in the dock water.

If you were asked how much she would rise in going from the dock into sea water it would be 4·7 inches, the difference between the two draughts.

Worked Example II.

If a ship is required to draw $21\frac{1}{2}$ feet in sea water, the density of which is 1026 ozs., what must she draw in water, the density of which is 1002 ozs ?

Density of the sea water, . 1026
Draft required in sea water, 21·5
5130
1026
2052
Density of dock water, 1002)22059·0(22 ft.
2004
2019
2004
15
12
1002)180·0(0·2 ins.
200·4

Ans.—Ship must draw 22 feet 0·2 inches in the dock water.

In this case she would rise 6·2 inches in passing from the dock into sea water.

Worked Example III.

The specific gravity of the water on the British Coast is 1025 ozs., and in the London Dock it is 1008 ozs. You are allowed 5 inches reduction in fresh water; how much would you load below your mark in the London Dock?

Rule.—As the difference between salt water and fresh water is to the difference between salt water and the water in which the ship is being loaded, so is the allowance in fresh water to the required allowance.

In this example it would be written—

as 25 is to 17 so is 5 inches to the required allowance.

Multiplying the second and third terms together, and dividing by the first, we get

$$\begin{array}{r} 17 \\ 5 \\ \hline 25)85(3{\cdot}4 \text{ inches} \\ \underline{75} \\ \hline 100 \\ 100 \\ \hline \end{array}$$

Examples for Exercise XX.

(1) Find the draught to which a ship must be loaded in water, the density of which is 1007 ozs., in order that she may have a draught of 19 feet in sea water, taking the density of sea water as 1026 ozs.

(2) Find the draught a ship must draw in water, the density of which is 1013 ozs., so as to be drawing 22 feet when in sea water, using 1025 as the sea water density.

(3) A ship is required to draw $23\frac{1}{2}$ feet when floating in sea water, the density of which is 1026 ozs., what must she draw in a dock where the density of the water is 1003 ozs.? Also how much would she rise in going from the dock into sea water?

(4) A vessel has a draught of 17 feet in sea water, the density of which is 1025 ozs. What will her draught be in water, the density of which is 1010 ozs.?

(5) The specific gravity of the water on the British Coast is 1025 ozs., and in the Albert Dock, Hull, is 1010 ozs. You are allowed $4\frac{1}{2}$ inches reduction for fresh water, how much would you load below your marks in the Albert Dock, Hull?

(6) The specific gravity of normal salt water is 1025 ozs.; at Fresh wharf it is 1005 ozs. The allowance when loading in fresh water is $3\frac{1}{2}$ inches. What is the allowance at Fresh wharf?

(7) The allowance for loading in fresh water is 5 inches. What would it be in Penarth Dock where the density of the water is 1016 ozs.? (Salt water 1025 ozs.)

(8) The specific gravity of salt water is 1025 ozs., and in Queen's Dock it is 1007. You are allowed to submerge your mark 6 inches in fresh water. How much would you submerge it in the dock?

CHARTWORK.

Candidates for Mates' and Masters' certificates will have already gone through what we may term the "spade work" in chart problems, so that the ones which are given here are more specially intended for practice purposes, in order to freshen the memory. All the examples for exercise may be worked on practice charts published by James Brown & Son, Glasgow, and may be obtained direct from that firm. The price of the English Channel and Tasmania charts are one shilling each, the St. George's Channel, Sumner chart, and Kyle Akin plan being ninepence. Threepence for postage in all cases, whether one or four are ordered.

Now a word or two about the naming of courses and bearings.

The **three figure notation** is being brought into general use.

Under this system true courses or bearings are expressed only in degrees, and are numbered from 000° at North (sometimes only 0°), increasing as they go round the compass **in a clockwise direction.** Thus 010° would represent N. 10° E. (true), 135° would be S. 45° E. (true), 270° would be West (true), and 359° would be N. 1° W. (true).

When a ship is steering on any cardinal point magnetic, or has an object bearing on any cardinal point magnetic, such course or bearing is written down as North, South, East, or West without any definition of its nature. Magnetic courses or bearings on any other than the cardinal points are always expressed in letters and numbers. For example, N. 72° E., written without a statement regarding its nature, would indicate a magnetic course or bearing.

When a **compass** course or bearing is expressed, the fact that it **is** a compass course or bearing will be clearly stated in the question.

If a true course or bearing is expressed in letters as well as numbers, such as N. 72° E., it will be followed by the word "true."

The only exception to the above rule occurs when, in a running fix, two bearings are taken of the same object or light, or two bearings each being of a different object or light. If the first bearing is given "by compass," the second is also to be taken as a compass bearing unless otherwise stated.

For example, we may say "a light bore N. 25° W. by compass, and after running West 15 miles it bore N. 25° E." The first bearing is given by compass, the second one is, therefore, also assumed to be by compass. The given course of West is magnetic.

The examples of chartwork given in this book are modelled on the latest ones which have been set at the examinations, and will give candidates a good idea of what they are likely to get.

Do not worry if you cannot make your answers exactly agree with those given facing the question. The same remark applies to those examples which are fully worked out. If you can obtain a result reasonably near them you will be doing quite well. A small deflection of a line will sometimes make a considerable difference in the final result.

The **names** of courses and bearings, also latitudes and longitudes, are most important. Be sure that you give them a name, and that it is the **right** name. Also, be very careful about the naming of your variation and deviation. Easterly written down as Westerly will probably mean that you do not get any marks for that particular problem, and quite possibly that **all** the marks for your chart will be lost. More failures are caused by incorrect names than by mistakes in figures.

The deviation card "ship's head magnetic" is not often given to candidates at the examinations. It has been used, however, in Worked Example V., as it is quite possible that it may be given at any time. Practically the same result will be obtained with both cards, but it is the **principle** which matters.

Masters are sometimes required, when working a chart problem, to correct their courses and bearings by means of a curve of deviations drawn on a Napier's diagram. This is explained in a few remarks following the Napier's diagrams in this book.

DEVIATION CARDS.

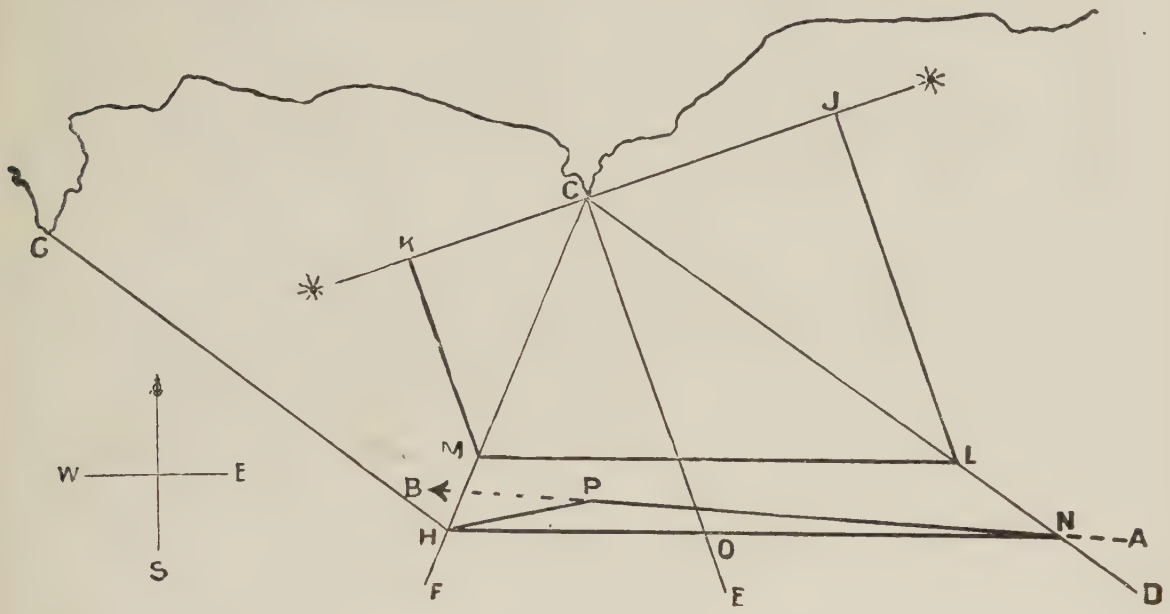
CARD No. 1.		CARD No. 2.	
Ship's head by Compass.	Deviation.	Ship's head magnetic.	Deviation.
North.	2° W.	North.	2° W.
N. by E.	4 W.	N. by E.	5 W.
N.N.E.	6 W.	N.N.E.	6 W.
N.E. by N.	7 W.	N.E. by N.	8 W.
N.E.	8 W.	N.E.	10 W.
N.E. by E.	10 W.	N.E. by E.	13 W.
E.N.E.	13 W.	E.N.E.	14 W.
E. by N.	14 W.	E. by N.	12 W.
East.	12 W.	East.	11 W.
E. by S.	11 W.	E. by S.	9 W.
E.S.E.	8 W.	E.S.E.	8 W.
S.E. by E.	6 W.	S.E by E.	5 W.
S.E.	4 W.	S.E.	4 W.
S.E. by S.	3 W.	S.E. by S.	3 W.
S.S.E.	2 W.	S.S.E.	1 W.
S. by E.	1 W.	S. by E.	1 W.
South.	0	South.	1 E.
S. by W.	1 E.	S. by W.	1 E.
S.S.W.	5 E.	S.S.W.	3 E.
S.W. by S.	7 E.	S.W. by S.	6 E.
S.W.	9 E.	S.W.	7 E.
S.W. by W.	11 E.	S.W. by W.	9 E.
W.S.W.	12 E.	W.S.W.	10 E.
W. by S.	14 E.	W. by S.	13 E.
West.	12 E.	West.	14 E.
W. by N.	10 E.	W. by N.	12 E.
W.N.W.	8 E.	W.N.W.	10 E.
N.W. by W.	6 E.	N.W. by W.	8 E.
N.W.	5 E.	N.W.	6 E.
N.W. by N.	3 E.	N.W. by N.	3 E.
N.N.W.	1 E.	N.N.W.	2 E.
N. by W.	1 W.	N. by W.	0

These deviation cards are **exactly** the same as those on page 251 (Vol. I.).

Diagram explaining the method of finding the **course and distance made good**, the ship's position, and the set and drift of the tide by means of three bearings of one object and a cross bearing of another. The true course steered (not made good) and distance run between the bearings is given.

A ship steering N. 85° W. (true) observes point *C* to be bearing N. 53° W. (true). After running 7 miles it bears N. 18° W. (true), and after having done another 5 miles on the same course it bears N. 23° E. (true). At the time of taking the third bearing

point G was observed to bear N. 52° W. (true). Required the ship's position when the third bearing was taken, the course and distance made good between the bearings, and the set and drift of the tide.



SCALE, 5 Miles to 1 inch.

Lay off the three bearings, which will be $D\,C$, $E\,C$, and $F\,C$.

The ship's position at the time of taking the third bearing is at H, which position is fixed by the intersection of that bearing by the cross bearing of point G.

Draw the line * * through point C at right angles to the middle bearing.

From C lay off $C\,J$ along this line to represent the distance steamed between the time of taking the first and second bearings, which is 7 miles (1·4 inches).

From C lay off $C\,K$ along this line in the other direction. This represents the distance steamed between the time of taking the second and third bearings, which is 5 miles (1 inch).

Draw the lines $J\,L$ and $K\,M$ parallel to $C\,E$.

These lines intersect the first and third bearings at L and M respectively.

Then $L\,M$ represents the course which the ship is making good over the ground, though not necessarily the actual distance. In this case it certainly cannot be the distance, because the ship was somewhere on the first bearing $C\,D$ at the start, and was at position H when the third bearing was taken at the finish.

Draw $N\,H$ parallel to $L\,M$.

$N\,H$ represents the actual course and distance made good over the ground between the times of taking the first and third bearings. This is about N. 88° W. (true), 16 miles (3·2 inches).

Knowing that the ship was at H when the third bearing was taken, she must have been at O when the second bearing was taken, and at N at the time of taking the first one.

Now, by laying off from N the course and distance which she has steamed, this will be 12 miles along the line $A\,B$, we should expect to find her at position P.

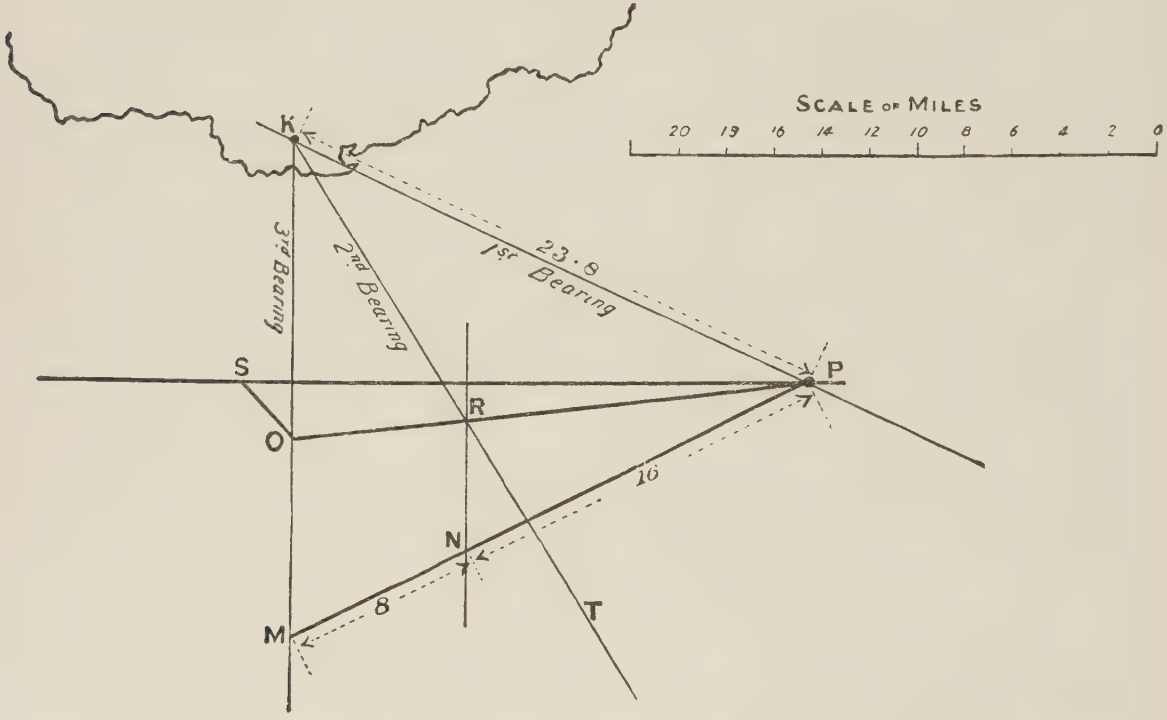
Having found that her real position is at H, the line $P\,H$ must represent the set and drift of the tide. This comes to about S. 79° W. (true), 4 miles (0·8 inch).

Given three true bearings of a point, the true course steered and the distance steamed between each bearing, and the ship's position on the first bearing.

To find the ship's position on the third bearing, the true course made good, and the set and drift since the first bearing was taken.

EXAMPLE.—A vessel was steering 270° when she picked up a light "*K*" dipping on the horizon, distance off 23·8 miles, and bearing 295°. After running 16 miles on her course it bore 328°, and after running another 8 miles it bore 000°.

Find the ship's position when abeam, the course and distance made good, and the set and drift since the light was first sighted.

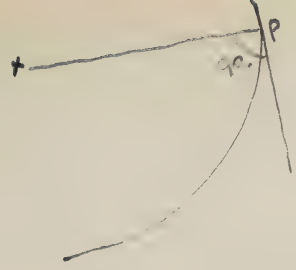


Lay off all the true bearings from *K*, and on the first bearing make *K P* = 23·8 miles, then *P* is the position of the ship on the first bearing, as she is 23·8 miles from the light. The ship steamed 24 miles between the first and third bearings, therefore with 24 miles in the compasses and the point of the compasses on *P* describe an arc cutting the third bearing at *M*. The distance steamed between second and third bearing was 8 miles, therefore from *M* make *M N* = 8 miles. Draw a line parallel to the third bearing through *N*, and where this meets the second bearing at *R* is the ship's position on the second bearing. Join *P R* and extend it to *O* on the third bearing. Then *P R O* is the course the ship has made good, and *O* her position on the third bearing.

To find the set and drift of the current since the vessel was at *P*, lay off the true course and distance steamed from *P* by making *P S* due west = 24 miles, then *S* is where the ship ought to be and *O* is where she actually is. *S O* is, therefore, the set and drift since her position was ascertained at *P*.

True course made good = S. 83° W. Set, S. 43° E. (true).

Distance, 21·7 miles. Drift, 3·5 miles.



Worked Example I.

(Worked on the St. George's Channel chart inset.)

Question 1.—**A vessel steering S. 7° W. by compass observed Bailey Head light, height 84 feet, to be dipping on the starboard beam. Height of eye 23 feet. Required the true course, also the ship's position and her distance from Bailey Head light.** (Use Dev. Card No. 1.)

Instructions for Working.—The visibility of a light in miles to an observer at sea level is obtained by multiplying the square root of the height of the light in feet by 1·15; similarly, the distance a light at sea level can be seen by an observer in a vessel is obtained by multiplying the square root of the height of eye in feet by 1·15. It follows, therefore, that when we have both **height of light** and **height of eye** to make allowance for, we must take the sum of these two calculations in order to obtain the visibility of the light. The distance off is obtained as follows :—

$$(\sqrt{84} \times 1{\cdot}15) + (\sqrt{23} \times 1{\cdot}15).$$

84 log =	2)1·924279	23 log =	2)1·361728
$\sqrt{84}$ log =	0·962139	$\sqrt{23}$ log =	0·680864
1·15 log =	0·060698	1·15 log =	0·060698
10·54 log =	1·022837	5·51 log =	0·741562
5·51			
16·05 miles.	Distance off Bailey Head Lt.		

With this distance as radius and Bailey Head Light as centre describe the circle *B P C*, the circumference of this circle will then be a **position line**—*i.e.*, the ship must be somewhere on this line. As Bailey Head Light was abeam on the starboard side we can get its true bearing by applying 90° to the right of the true course. Thus we have two position lines, the circle of equal distance and the true bearing, and as the vessel is on both of these lines, she must be at their point of intersection at *P*.

The ship's course being given by compass, it must be turned into a true one by applying the deviation (taken from the card), and the variation.

Compass course, . .	S. 7° W.	R. of S.	
Dev. from card, . .	1	E. R.	
Magnetic course. . .	S. 8	W. R. of S.	Ship's position { Lat., 53° 24′ N. Long., 5° 41½′ W.
Corrected variation, .	17	W. L.	
True course, . . .	S. 9°	E.	

From the ship's position at *P*, project the course line *P H* in a 171° direction.

WORKED EXAMPLE 1 (*Continued*).

Question 2.—**Three hours after fixing the position of the ship in the last question, a steady speed of 8 knots being maintained ; Mizen Head was observed to be bearing 85° on the starboard bow and at the same time Wicklow Head Lt. bore 25° abaft the starboard beam. Find the ship's position and the set and drift of the current experienced since the ship was abeam of Bailey Head Lt.**

INSTRUCTIONS FOR WORKING.—From P measure off along the course line the distance run since this position was obtained, which was 24 miles ; this gives the expected position E. The bearings of Wicklow Head Lt. and Mizen Head can be laid off with Field's rules by treating the course line $P\,H$ as a meridian and the angle of the bearing from the bow as a course ; or they can be obtained from the true course as follows :—

True course	= S.	9° E. (left)
Angle of Mizen Head on bow . .	=	85° (right)
True bearing of Mizen Head . .	= S.	76° W.

True course	= S.	9° E. (left)
Angle of Wicklow Head Lt. on bow .	=	115° (right)
	S.	106° W.
		180
True bearing of Wicklow Head Lt. .	= N.	74° W.

The point of intersection of these two bearings at A is the actual position of the ship, the set and drift is, therefore, $E\,A$, which is reckoned from the expected to the actual position of the ship.

Ship's position . .	{ Lat.	52° 54′ 30″ N.
	{ Long.	5° 43′ 30″ W.
Set of current . .	= 219°	
	or S. 56° W. Magnetic.	
Drift . . .	= 8 miles, or $2\frac{3}{4}$ miles per hour.	

WORKED EXAMPLE I. (*Continued*).

Question 3.—**Whilst on the last-mentioned course Rosslare Point Lt. bore 60° on the starboard bow, and after running for 1h. 15m. at 8 knots the same light bore 20° abaft the starboard beam. Find the ship's position and her distance from Rosslare Point Lt. when the second bearing was taken, allowing for a current as ascertained in Question 2. Required also the distance from Tuskar Rock Lt. when abeam.**

Position of Rosslare Point Lt. :—Lat. 52° 21′ N., Long. 6° 22′ 40″ W. Put it on the chart if it is not marked on your copy.

INSTRUCTIONS FOR WORKING.—Lay off the two bearings of Rosslare Point Lt. as explained when laying them off in Question 2. From any position (K) on the first bearing draw a line parallel to the ship's true course, and on it measure off from K to L the distance steamed in $1\frac{1}{4}$ hours, which is 10 miles.

From L lay off the current ascertained in the preceding question. This was S. 39° W. (true) at $2\frac{3}{4}$ knots, which in $1\frac{1}{4}$ hours will be $3\frac{1}{3}$ miles. This will reach the mark M. Through M draw a line parallel to the first bearing. The point where this line intersects the second bearing at N is the ship's position at the time of taking that bearing. Now, $K\,M$ is the course and distance **made good** between the time of taking the two bearings, and is the result of the course and distance steamed and the current experienced during that time. If we draw a line parallel to $K\,M$ through N (the ship's position when the second bearing was taken) it will represent the vessel's **actual track** over the ground. This is the line $Q\,N\,O\,U$. The beam bearing of an object is always at right angles to the **direction of the ship's head,** which is represented by the line $K\,L$. We, therefore, draw a line at right angles to $K\,L$, and the point where this line ($O\,R$ on chart) meets the actual track of the vessel at O will be the ship's position when abeam of Tuskar Light.

True course,	S. 9° E.	True course,	S. 9° E.
Angle on bow,	60° (to the right)	Angle on bow,	110° (to the right)
First true bg. of Rosslare Pt.,	S. 51° W.		S. 101° W.
			180
		Second true bg. Rosslare Pt.,	N. 79° W.

Ship's position on second bearing { Lat. 52° 19′ N. / Long. 6° 5′ W.

Distance from Rosslare Point, $12\frac{1}{2}$ miles.

Distance from Tuskar Rock when abeam, 3 miles.

Worked Example I. (*Continued*).

Question 4.—**Find the course to steer by compass from the last position with Tuskar Rock Lt. abeam, to reach a position 000° from Strumble Head Lt. distant 5 miles. Make proper allowance to counteract the effect of a current setting S. 58° W. at 2½ knots, and allow 5° leeway for a N.N.E. wind, the ship's speed being 8½ knots. Give the distance steamed and the time taken to reach the destination.** (Deviation Card No. 1.)

Instructions for Working.—Mark off the position of the destination at a distance of 5 miles due North (true) from Strumble Head Lt. Call it *S*. Join *O S* with a straight line. If there was not any current, *O S* would be the true course.

To find the course to steer to counteract the effect of a current setting S. 58° W. (magnetic), lay off a line in a S. 58° W. magnetic direction from *O* to represent the set of the current.

No time being specified in the question, we must choose some convenient interval of time on which to base our calculations, let us say two hours. Now, in two hours the current will set 5 miles, so we measure off 5 miles along the current line from *O* and make the mark *T*. *O T*, then, represents the set of the current in two hours.

The ship's speed being 8½ knots, in two hours she will do 17 miles. With this distance in the compasses, place one leg on *T* and mark the position where the other leg meets the line *O S*. Name this mark *W*. Join *T W*, then *T W* is the course to steer to counteract the current *O T*. As the vessel will have to steer this course until she reaches her destination, draw a line parallel to *T W* through *S*. This line meets *O T* (extended) at *X*, and *X S* represents the distance which the ship will have to steam to reach *S*. The time occupied is found by proportion, as shown below.

The correction for leeway is not projected on the chart, but is applied to the true course **after** it has been taken from the chart. Remember that it must be allowed **to windward**—in other words, **towards the wind**—in order to counteract the effect of the ship being set to leeward or away from the wind.

It is important that the leeway should be applied before the deviation is taken from the card, as the deviation changes with the direction of the ship's head.

True course, . . .	N. 83° E. R.
Leeway (N.N.E. wind), .	5 L.
	N. 78° E. R.
Variation, . . .	17 W. R.
Magnetic course, . .	N. 95° E. R.
	180
Magnetic course, . .	S. 85° E. L.
Deviation, . . .	10 W. R.
Compass course, . .	S. 75° E.
Distance steamed. . .	51¾ miles.
Time occupied, . .	6 hrs. 5·4 mins.

To Find the Time taken to reach Destination.

As 8½ : 51¾ :: 1 hr. to time.

8·50)51·75(6·09 hours.
51 00

·09 hours
60

5·40 minutes

7500
7650

Worked Example II.

(To be worked on the practice chart of Tasmania.)

Working inset.

Question 1.—**The position of the ship by dead reckoning was Latitude 40° 40′ S., Longitude 143° 40′ E. W/T bearing of the ship from Hobart D.F. Station in Lat. 42° 54′ S., Long. 147° 15′ E. was 310° and W/T bearing of the ship from Cape Grim D.F. Station in Lat. 40° 42′ S., Long. 144° 43′ E. was 271·5°. Required the position of the ship by these W/T bearings.**

Instructions.—To obtain a fix by W/T bearings proceed as follows :—Find the middle latitude between the dead reckoning position and W/T station, and also the difference of longitude. Multiply the sine of Mid. Lat. by D. Long. (in minutes), and obtain the convergency. Divide the convergency by 2 to get the ½ convergency, and apply it to the bearing given in question.

Do the same with both bearings given by W/T stations.

To apply :—As we are in the Southern Hemisphere, and the ship is West of both stations, the ½ convergency must be added to the W/T bearings from the stations. See working below.

Hobart D.F. Station Lat.,	42° 54′ S.	Long.,	147° 15′ E.
D.R. position of ship, Lat.,	40 40 S.	Long.,	143 40 E.
Sum of Lats.,	83° 34′	D. Long.,	3° 35′
÷ by 2 = Mid. Lat.,	41 47		60
			215′
Mid. Lat.,	41° 47′ sin 9·823680		
D. Long.,	215′ log 2·332438		
Convergency,	143·2′ log 2·156118	W/T bearing,	310°
½ Convergency, 71·6′ = 72′ = 1° 12′ = 1·2°.		½ Convergency,	+ 1·2
		Mercatorial bearing,	311·2

Cape Grim D.F. Station, Lat.	40° 42′ S.	Long.,	144° 43′ E.
D.R. position of ship, Lat.	40 40 S.	Long.,	143 40 E.
Sum of Lats.,	81° 22′	D. Long.,	1° 3′
÷ by 2 = Mid. Lat.,	40 41		60
			63′
Mid. Lat.,	40° 41′ log sin 9·814166		
D. Long.,	63′ log 1·799341		
Convergency,	41·07′ log 1·613507	W/T bearing,	271·5°
½ Convergency,	20·53 = ·34°.	½ Convergency,	+ ·34
		Mercatorial bearing,	271·84°
			or 272°

The position of the ship is fixed by the intersection of these two lines drawn from the W/T stations. Point *J* on the chart.

WORKED EXAMPLE II. (*Continued*).

Question 2.—**From this position obtained by the W/T bearings, a course was set to pass 15 miles off Cape Sorell Lt. when abeam. Using Deviation Card No. 1, find the course to steer by compass and also the distance to steam to bring the light abeam.**

INSTRUCTIONS.—Take, from the graduated meridian abreast of Cape Sorell Lt., 15 miles in your compasses, and describe an arc round the light. From the point of departure *J* draw a tangent to this arc. Now draw a line at right angles to this tangent on to the light, and obtain the beam bearing of the light (*K* on the chart). The tangent to the arc is the course, which must be corrected, and turned into a compass course. The distance to bring Cape Sorell Lt. abeam (*J K*) measured on the graduated meridian is found to be 106·5 miles.

True Course, . .	S. 25° 0′ E.
Variation, . . .	8 0 E.
Magnetic course, . .	S. 33° 0′ E.
Deviation, . . .	2 40 W.
Compass course, . .	S. 30° 20′ E.

S.S.E.	= S. 22½° E.	1°
Dev.,	2° W.	8½
	S. 24½ E.	12)8½
		40 nearly.

S.F. by S.	= S. 34° E.	Dev., 2° 0′ W.
Dev..	3° W.	Con., + 40
	S. 37° E.	Dev., 2° 40′ W.

Distance to bring light abeam, 106½ miles.

Question 3.—**While on this course Cape Sorell Lt. bore S. 75° E. by compass, and after continuing for 1·5 hours at rate 12, the light was found to be exactly abeam. Required the ship's position when abeam, and her distance from Cape Sorell Light.**

INSTRUCTIONS.—Correct the compass bearing of Cape Sorell Light, using the deviation found in the preceding question. There is no need to correct the second bearing of the light because it is abeam, or at right angles to the course. Plot these lines, and from where the first bearing intersects the course line, measure along the course line 18 miles (the distance steamed between the bearings), and through this point draw a line parallel to the first bearing of the light. Where it crosses the second or beam bearing is the position of the ship when the light is abeam (*L* on chart).

CAPE SORELL LT.

Compass bearing, . .	S. 75° E.
Deviation, . . .	3 W.
Magnetic bearing, . .	S. 78° E.
Variation, . . .	8 E.
True bearing, . .	S. 70° E.

CAPE SORELL LT.

Abeam, requires no correction

Lat., ...	42° 18½′ S.
Long., ...	144° 48′ E.

Distance from Cape Sorell Light, 18 miles.

WORKED EXAMPLE II. (*Continued*).

Question 4.—**Proceeding on this course for a further 3 hours at the same speed, the western extremity of Point Hibbs was observed to be bearing N. 5° W. by compass, and at the same instant the Signal Staff on Rocky Point bore by the same compass S. 71° E. Find the position of the ship and the set and drift experienced since determining the position by the running fix off Cape Sorell Light.**

INSTRUCTIONS.—As we are still continuing on the same course as in the last question, we draw a line parallel to the original course line from L. From L, measure along this course line a distance of 36 miles (3 hours' steaming), this gives us the expected position M. After applying the same compass error to the given compass bearings of Point Hibbs and Rocky Point Signal Staff, to turn them into true bearings, we plot them down, and their point of intersection N gives us the real position of the vessel. Joining up the expected position M with the real position N, we obtain the set and drift of the tide during the previous three hours.

WESTERN EXTREMITY OF POINT HIBBS.		ROCKY POINT SIGNAL STAFF.	
Compass bearing,	N. 5° W.	Compass bearing,	S. 71° E.
Deviation,	3 W.	Deviation,	3 W.
Magnetic bearing,	N. 8° W.	Magnetic bearing,	S. 74° E.
Variation,	8 E.	Variation,	8 E.
True bearing,	North.	True bearing,	S. 66° E.

Lat. 42° 54½′ S. Long. 145° 15′ E.
Set, 128·5°. Drift, 6 miles, or at 2 knots.

Question 5.—**From the position thus found by cross-bearings, reset the course by compass (Deviation Card No. 1) to a position 9 miles, 264° from South-west Cape, to counteract the effect of the current ascertained in the previous question, and also find what distance will be made good in 3 hours towards the destination, and the distance from South-west Cape at the end of that time.**

INSTRUCTIONS.—To reset the course to the position 9 miles, 264° from South-west Cape, we prick this position on the chart (O) and draw a line from the real position N, found by cross-bearings in the previous question, to O. This gives us the course to be made good $N\,O$. Now, from the position by cross-bearings (N) lay off a tide similar to that found in the last question; this will be a continuation of the line $M\,N$, indicated by arrow head.

From N measure in the direction of the arrow head the distance the ship will be set in 3 hours; this is 6 miles, and reaches the point P. Take the distance steamed in 3 hours—that is, 36 miles—in the compasses, and with one leg on P mark the point Q on the line $N\,O$. A line from P to Q indicates the true course to steer which must be brought to a compass course. $N\,Q$ represents the distance made good in 3 hours.

True Course,	S. 29° E.	S.E. by S.,	S. 34° E.
Variation,	8 E.	Deviation,	3 W.
Magnetic course,	S. 37° E.		S. 37° E.
Deviation,	3 W.		
Compass course,	S. 34° E.		

Distance made good in 3 hours, 42 miles.
Distance from South-west Cape, 13 miles.

Worked Example III.

Question 1.—**Approaching the south-west coast of Tasmania on a compass course of E.S.E. a Lt. Gp. Fl. (2) ev. 30 secs. was observed to be bearing N. 87° E. by compass. 1·2 hours later it bore N. 60° E. by compass, and 48 minutes later still it was abeam. Required the position of the ship when abeam, also the strength of the current, the set being estimated to be 203° and the speed of the ship 10 knots by revolutions.** (Use Deviation Card No. 1.)

Instructions.—As the course by compass is given (E.S.E.), we take the deviation direct from the card for that point and apply it to same, together with the variation, and obtain the true course. This same error is also applied to the three bearings taken of the Lt. Gp. Fl. (2) ev. 30 secs. to turn them into true bearings. It is a coincidence that the variation and deviation are equal in amount but opposite in name, thus making no compass error, and the compass bearings are, therefore, true ones.

Draw these three bearings on to the light, and through the light draw a line at right angles to the middle of the three bearings. Now take the distance steamed between the first and second bearings; in 1 hour 12 minutes this will be 12 miles, and measure it along this line to the left of the light, reaching point *R*, also take the distance steamed between the second and third bearings; in 48 minutes this will be 8 miles, and measure it along this line to the right of the light, reaching point *S*. From *R* and *S* lay off two lines parallel to the middle bearing, and let them intersect the first and third bearings in points *T* and *U*. These two points joined together will give the actual direction in which the ship is moving over the ground.

Draw from the point *T* on the first bearing the true course being steamed (S. 67° E.) and measure along it the distance steamed in the two given times, 1h. 12m. + 0h. 48m. = 2 hours, which at 10 knots = 20 miles. Name this point *V*. From *V* draw the given set of the current 203° on to the course being made good, reaching the point *W*. You will thus obtain the amount the tide has set you during the two hours (*V W*) and also the actual distance made good (*T W*). We then draw through the point *W* a line parallel to the first bearing, and the point where this parallel line meets the third bearing is the actual position of the ship at the time of taking the third bearing or when abeam (*X*).

Compass Course, . . .	S. 67° 30′ E.	
Dev. direct from card, . .	8 0 W.	Dev. and var. practically the same value, therefore the error is assumed to be nil.
Magnetic course, . . .	S. 75° 30′ E.	
Variation, ...	8 30 E.	The three bearings of the light are, therefore, both compass and true.
True course, ...	S. 67° 0′ E.	

First bearing 087°, second bearing 060°, third bearing 023° or abeam.

Position of the ship, Lat. 43° 50½′ S., Long. 146° 11′ E.

Tide set 2 miles in 2 hours, ∴ Rate = 1 knot.

Worked Example III. (*Continued*).

Question 2.—**When abeam of this light (Lt. Gp. Fl. (2) ev. 30 secs.) the course was reset to pass 6 miles off Whale Head when abeam, and after proceeding for 2·5 hours at rate 10, cross bearings were taken to fix the ship's position as follows :—Piedra Blanca S. 65° E. and Whale Head N. 22° E., both by the same compass. Required the course to steer by compass, the position of the ship by the cross bearings, and the set and drift of the tide affecting the ship since the course was reset.** (Deviation Card No. 1.)

Instructions.—From the position (X) the course is reset to pass 6 miles off Whale Head. Draw a circle of 6 miles radius round Whale Head, and draw a tangent to it; measure 25 miles (distance steamed in 2·5 hours) from X along it, and obtain the expected position (Y). Correct the true course and obtain the compass error, and apply same to the compass bearings of Piedra Blanca and Whale Head to turn them into true bearings. Plot them on the chart, and where they intersect at Z is the real position. The line $Y\ Z$ is the set and drift experienced in the 2·5 hours.

True course,	N. 79° 0′ E.
Variation,	8 30 E.
Magnetic course,	N. 70° 30′ E.
Deviation,	13 0 W.
Compass course,	N. 83° 30′ E.

E. by N. =	N. 79° E.	2°	
Dev.	14 W.	6	Dev., 14° W.
		13)12	Corr. — 1
	N. 65° E.	1	Corr. dev., 13 W.
East =	N. 90° E.		
Dev.,	12 W.		
	N. 78° E.		

Piedra Blanca.		Whale Hd.	
Compass bearing,	S. 65° E.	Compass bearing,	N 22° E.
Error,	4½ W.	Error,	4½ W.
True bearing,	S. 69½° E.	True bearing,	N. 17½° E.

Lat. 43° 45½′ S. Long. 146° 50′ E.

Set 133°. Drift 4 miles, or Rate 1·6 knots.

WORKED EXAMPLE III. (*Continued*).

Question 3.—**Reset the course again to maintain a distance of 5·5 miles from Tasman Head to counteract the effect of a tide similar to that determined in the previous question, and when Tasman Head bears 270° alter the course to an anchorage with Iron Pot Lt. dead ahead and distant 2 miles.**

Using Dev. Card No. 1, give the course to steer and the distance to steam to the position where Tasman Head bears 270°, and also give the course to steer to the anchorage (both by compass). If on the final course the tide is dead astern and the anchorage is made in exactly 2 hours, required the rate of the tide, the speed of the ship being 10 knots throughout.

INSTRUCTIONS.—Draw a circle round Tasman Head 5·5 miles in radius, and from the "fix" by cross bearings in the previous question (*Z*) a tangent is drawn to this circle. As the course requires to be carried on until Tasman Head bears 270°, we produce it to intersect a line drawn 090° from Tasman Head (*A*). This will obtain for us the real course and distance to be made good (*Z A*) to arrive at that position. As the tide found in the previous question must be counteracted, the direction is laid off from the starting point (*Z*). It should be observed that no specified time is given in the question, therefore any interval of time may be assumed. To save the time taken in calculating by proportion and to reduce the possibility of a mistake being made, it is usual to assume the same time used in determining the amount of the current. Extend the line *Y Z*, measure along it from *Z*, 4 miles, the distance set in 2·5 hours (*Z B*), and from *B*, 25 miles is fitted on to the course line to be made good (*Z A*) at point *C*. *B C* connected together gives the true course to be steered, and a parallel line to it (shown dotted) from the extended current line to the position (*A*) off Tasman Head gives the distance to be steamed to reach that position.

From the position of the ship (*A*) when Tasman Head bears 270°, draw a line to Iron Pot Lt., measure 2 miles from it, and mark the point *D*. This will be the anchorage, or destination. Correct this true course to obtain the compass course, and measure the distance along it; this will be found to be 26·5 miles. As the ship makes the anchorage in 2 hours, steaming at 10 knots, she must have experienced 6·5 miles of fair tide or at the rate of 3·25 knots.

True course, ...	N. 54° E.	N.E. = N.	45° E.
Variation, ...	9 E.	Dev.,	8 W.
Magnetic course, . . .	N. 45° E.		N. 37° E.
Deviation, ...	10° W.		
Compass course, . . .	N. 55° E.	N.E. by E. = N.	56° E.
		Dev.,	10° W.
			N. 46° E.

$9)\overline{16}$ 2 nearly

8° W
Corr. + 2
10° W.

Distance to steam to the position off Tasman Head, 37·5 miles.

True course, ...	N. 16° W.	N.N.W. = N.	$22\frac{1}{2}$° W.
Variation, ...	9 E.	Dev.,	1 E.
Magnetic course, . . .	N. 25° W.		N. $21\frac{1}{2}$ W.
Deviation, ...	2° E.		
Compass course, . . .	N. 27° W.	N.W. by N. = N.	$33\frac{3}{4}$° W.
		Dev.,	3 E.
			N. $30\frac{3}{4}$° W.

2
$3\frac{1}{2}$
$9)\overline{7}$ 1 nearly

1° E.
Corr. + 1
2° E.

Distance on last course = 26·5 miles.

Arrived at destination in 2 hours at 10 knots = 20 miles, therefore there was a fair tide of 6·5 miles or at rate 3·25 knots.

Example for Exercise I.

(To be worked on the Chart of Tasmania.)

Proceeding through Bass Strait to the Eastward in hazy weather, soundings were taken at intervals of one hour, the ship steaming at a reduced speed of 6 knots. At 6 p.m. 44 fathoms, mud ; at 7 p.m. 41 fathoms ; at 8 p.m. 38 fathoms ; at 9 p.m. 27 fathoms, coarse sand and shells. (All corrected soundings).

The course being made good was estimated to be 102°.

Soon after obtaining the cast at 9 p.m. the fog lifted, and Goose Island light was observed to be bearing 49° from ahead on the port bow. Speed was increased to 11 knots, and at 10 p.m. the light was found to be abeam. From the position thus obtained set a course by compass (using Deviation Card No. 1) to pass Swan Id. Light at a distance of 5 miles, and state how long you will take and how far you will have to steam to bring it abeam. The tide may be assumed to be ebbing at 2 knots in approximately the same direction as the course of the ship.

Still steering on the same course and at the same speed, some time later Swan Id. Light was observed to be bearing N. 84° W. by compass, and at the same time Eddystone Point Light bore S. 24° W. by the same compass. Required the position of the ship at that time, and her distance from Swan Id. Light.

From the position obtained by these cross bearings, reset the course by compass to pass Cape Forestier Light 10 miles distant when abeam on the approaching course. Proper allowance to be made to counteract the effect of a current estimated to be setting 135° at 1·5 knots. Required also the time you will take to reach the position abeam of Cape Forestier Light, the ship steaming at 12 knots by revolutions.

Answers to Example I.

True course,	. .	S. 66° E. L. of S.
Variation,	. .	9 E. L.
Magt. course,	. .	S. 75° E. L. of S.
Deviation,	. .	8 W. R.
Comp. course,	. .	S. 67° E

E.S.E. from card,	.	S. 67½° E. L. of S.
Dev. on E.S.E.,	.	8 W. L.
		S. 75½° E.

Distance over the ground to bring Swan Is. Lt. abeam is 21·5 miles.

As the ship is steaming at 11 knots, but making 13 knots over the ground, the time she will take to bring the light abeam will be $\frac{21\cdot5}{13}$, which is **1·65 hours, or 1h. 39m.**

As she is doing 11 knots through the water, the distance she will steam will be **11 × 1·65, which is 18·15 miles.**

If only the distance to steam was required, it could be found by direct proportion, as under :—

As 13 : 11 :: 21·5 to distance.

21·5
11
13)236·5(18·2 miles
13
106
104
25
26

Swan Island Lt.

Compass bearing,	.	N. 84° W. L.
Error,	. .	1 E. R.
True bearing,	. .	N. 83° W.

Eddystone Pt. Lt.

Compass bearing,	.	S. 24° W. R.
Error,	. .	1 E. R.
True bearing,	. .	S. 25° W.

Lat. 40° 46′ S. Long. 148° 29½′ E. Distance, 16½ miles.

True course,	. .	S. 1° W. R. of S.
Variation,	. .	9½° E. L.
Magt. course,	. .	S. 8½° E. L. of S.
Deviation,	. .	1 W. R.
Comp. course,	. .	S. 7½° E.

South from card,	=	S. 0°
Dev. on South	=	0
Less course	=	S. 0°
S. by E. from card	=	S. 11° E.
Dev. on S. by E.	=	1 W.
		S. 12° E.

1°
8·5
12)8·5
·71 (call it 1°)

Example for Exercise II.

(To be worked on the chart of Tasmania.)

Using latitude by D.R. 40° 50′ S., the longitude obtained by an observation of a celestial object on the prime vertical was 143° 47′ E., and at the same time a cast of the deep-sea lead gave 70 fathoms (corrected), sand and shells. The course was set to pass 20 miles outside Cape Sorell Light, allowing for a leeway of 5°, wind S.W., and a current estimated to be setting 060° at 2 knots. Required the course to steer by compass and the approximate distance that will be made good in 8 hours, ship steaming 10 knots by revolutions. (Use deviation card No. 1.)

Cape Sorell light was observed dipping bearing 119° with height of eye 42 feet, at which time the course was reset to S. 18° E. by compass. Required the position of the ship and her distance from Point Hibbs when abeam. No leeway to be allowed, the wind having decreased considerably in strength. The current was considered to be setting 140° at rate 2, and the ship to be making 10 knots, as in the previous question.

From this position reset the course to pass 3 miles off South West Cape to a position with Maatsuyker Id. Lt. bearing 070°. Give the compass course to steer and the distance. After running on this course for 3 hours at 10 knots, Rocky Pt. was found to be abeam, and at the same time Mt. 2445 (De Witt Range) bore by compass S. 80° E. Required the position of the ship and also the set and drift of the current since the course was reset off Point Hibbs.

From this position obtained by the cross bearings find the course to steer and also the distance to steam to reach the final point off Maatsuyker Id. Lt., making due allowance for a similar set and drift to that just ascertained.

Answers to Example II.

True course to counteract for tide only, S. 15° E.
True course to counteract also for leeway, S. 10° E.

True course,	S. 10° 0′ E.	S. 11° E.	1°
Var.,	8 0 E.	1 W.	6
Mag. course,	S. 18° 0′ E.	S. 12° E.	12)6
Dev.,	1 30 W.		½
Comp. course,	S. 16° 30′ E.	S. 22° E.	
		2 W.	
		S. 24° E.	Dist. approx. 77 miles.

Comp. course,	S. 18° E.		
Dev. from card,	1½° W.		
Mag. course,	S. 19½° E.	Lat. 42° 40½′ S.	
Var.,	8 E.	Long. 144° 59½′ E.	
		Distance from Point Hibbs when abeam, 12 miles.	
True course,	S. 11½° E. steered		

True course,	S. 38° E.	S. 34° E.	1°
Var.,	8 E.	3 W.	9
Mag. course,	S. 46° E.	S. 37° E.	12)9
Dev.,	4 W.		¾
Comp. course,	S. 42° E.	S. 45° E.	
		4 W.	
		S. 49° E.	Distance, 80 miles.

Rocky Pt. Signal Staff.

Abeam.

Mt. 2445 (De Witt Range).

Compass bearing,	S. 80° E.
Error,	4 E.
	S. 76° E.

Lat. 43° 4½′ S. Long. 145° 22½′ E.
Set, 248°. Drift, 2 miles, or at Rate ⅔ knots.

True course.	S. 44° E.	S. 45° E.	2°
Var.,	8 E.	4 W.	3
Mag. course	S. 52° E.	S. 49° E.	13)6
Dev.,	4½° W.		½
Comp. course,	S. 47½° E.	S. 56° E.	
		6 W.	
		S. 62° E.	

Distance to steam, 51½ miles.

Example for Exercise III.

(To be worked on the chart of Tasmania.)

From a position in Lat. 41° 25′ S. Long. 149° 4′ E. Set a course by compass, (using deviation card No. 1) to bring Tasman Id. Lt. abeam, distant 3 miles, Whilst on this course C. Forestier Lt. was observed to be bearing by compass S 47° W., after proceeding for 9 miles it bore S. 74° W., and after doing another 6 miles it bore N. 80° W., whilst at the same moment the southern extremity of Schouten Id. bore S. 67° W. All these bearings being taken by the same compass.

Find the position of the ship at the time of taking the cross-bearings, and also find the set and drift of the tide experienced since taking the first bearing of C. Forestier Lt., the ship having been steaming for 1·25 hours at rate 12 until fixing her position by cross-bearings. Give also the distance made good from the initial point of departure.

Reset the course to pass 3 miles off Tasman Id. Lt. as before, to counteract the effect of the tide determined in the previous question.

Give the compass course to steer, the distance to steam, and the time occupied in bringing the light abeam. Ship steaming at rate 12.

When abeam of Tasman Id. Lt. reset the course to pass 2 miles off C. Raoul, and when Wedge Id. opens just clear of Tasman Peninsula, alter course to reach an anchorage in Trumpeter Bay, N. Bruny Id.

Give the courses to steer by compass, making due allowance for a tide setting 200° at 2 knots on the first course, and 160° at 2 knots on the second course.

Give, also, the time occupied in reaching the anchorage, since resetting the course off Tasman Id., the ship maintaining a regular speed of 12 knots.

Answer to Example III.

True course, . . .	S. 21½° W.
Var., ...	9½ E.
Mag. course, . . .	S. 12° W.
Dev., ...	1 E.
Comp. course, . . .	S. 11° W.

S. by W. = S. 11° W.
Dev. 1 E.
S. 12° W.
Call error 11° E.

	Cape Forestier Light. 1st bearing.	2nd bearing	3rd bearing.	South End Schouten I.
Compass bearing, . .	S. 47° W.	S. 74° W.	N. 80° W.	S. 67° W.
Error, ...	11 E.	11 E.	11 E.	11 E.
True bearing, . . .	S. 58° W.	S. 85° W.	N. 69° W.	S. 78° W.

Lat. 42° 16¾′ S. Long. 148° 42′ E. Set 169°. Drift 3¼ miles. Distance made good, 54 miles.

True course, . . .	S. 32° W.	
Var., ...	9½ E.	
Mag. course, . . .	S. 22½° W.	
Dev., ...	4 E.	
Comp. course, . . .	S. 18½° W.	Distance 56 miles at rate 12 . = h. 4 m. 40

True course, . . .	N. 85° W.	S. 67½° W.	2°
Var., ...	9½ E.	12 E.	6
			14)12
	N. 94½° W.	S. 79½° W.	1
Mag. course, . . .	S. 85½ W.		
Dev., ...	13 E.	S. 79° W.	12° E.
		14 E.	+ 1
Comp. course, . . .	S. 72½° W.	S. 93° W.	13° E.

Distance 14 miles at rate 12 . = 1 10

True course, . . .	N. 58° W.	N. 79° W.	2°
Var., ...	9½ E.	10 E.	8
			10)16
Mag. course, . . .	N. 67½° W.	N. 69° W.	1½
Dev., ...	9½ E.		
		N. 67½° W.	8° E.
Comp. course, . . .	N. 77° W.	8 E.	+ 1½
		N. 59½° W.	9½° E.

Distance 20 miles at rate 12 . = 1 40 +

Time occupied, . . . 2 50

Example for Exercise IV.

(To be worked on Brown's St. George's Channel Chart.)

(Deviation Card No. 1.)

Ques. 1.—On June 14th, 1925, at 04h. 00m. (4h. 0m. A.M.), a vessel was steering in a south-westerly direction in foggy weather off Carnarvon Bay light-vessel when the following soundings were taken:—Log 4, sounding 29 fathoms; log 8, sounding 33 fathoms; log 13, sounding 44 fathoms (all soundings reduced to chart datum). Ship's speed, 9 knots.

At the time of taking the last sounding the weather cleared and the course was altered to S. 15½° W. by compass. Having altered the course, a glimpse of Bardsey Island light was obtained at the same moment bearing 39° on the port bow.

After steering on this course for 1¼ hours at 10 knots Bardsey light was abeam. Find the ship's position and her distance from Bardsey Island at this time, allowing for an approximate set and drift of S. 68° W. at 2 knots.

Ques. 2.—At 06h. 15m. (6h. 15m. A.M.) the course was altered to S. 57° W. by compass, and speed increased to 13 knots. At 08h. 15m. (8h. 15m. A.M.) the ship was stopped for repairs, which occupied 3 hours. Since 6h. 15m. A.M., the average set of the current, was estimated to be 000° at the rate of 2 knots, find the position of the ship when the repairs were finished, and the compass course she will have to steer to reach a position with Tuskar Rock bearing 180° distant 5 miles. The wind being E.S.E. strong, due allowance to be made for 3° of leeway, and for the tide, now setting 350° at the rate of 2½ knots. Since completing repairs the ship had maintained a steady 10 knots. Required, also, the time of arrival at destination.

Answers to Example IV.

Ques. 1.

Compass course, . . S. 15½° W. R. of S.
Deviation. . . . 2½ E. R.

Magnetic course . . S. 18° W. R. of S.
Variation. . . . 17 W. L.

True course, . . . S. 1° W.

Dev. from card on S. by W. = 1° E.
Dev. from card on S.S.W. = 5 E.

Difference in deviations = 4

$$11\overline{)17}(1\cdot5$$
$$\underline{11}$$
$$60$$
$$\underline{55}$$

Ship's position, { Lat., ... 52° 45′ 45″ N.
Long., ... 5° 10′ 0″ W.

Distance from Bardsey Is. Lt., . . . 13½ miles.

Ques. 2.

Compass course, ... S. 57° W. R. of S.
Deviation from card, ... 11 E. R.

Magnetic course, ... S. 68° W. R. of S.
Variation, ... 17 W. L.

True course steered, ... S. 51° W. (6h. 15m. to 8h. 15m.)

Position of ship at 8h. 15m. A.M. { Lat., . 52° 33′ N.
4 miles of current allowed { Long., . 5° 40′ W.

Position of ship when repairs were finished at 11h. 15m. A.M., 6 miles more current allowed. { Lat., . 52° 39′ N.
Long., . 5° 40′ W.

True course to destination if no current, . S. 42° W.

True course to destination, current allowed, S. 30° W. R. of S.
Leeway, ... 3° to the left

True course to steer, ... S. 27° W. R. of S.
Corrected variation, ... 17 W. R.

Magnetic course, ... S. 44° W. R. of S.
Deviation, ... 7½ E. L.

Compass course, ... S. 36½° W.

From Deviation Card.

Ship's head S.W. by S. = S. 34° W. R.
Dev. on S.W. by S. 7 E. R.

Lesser course, S. 41° W.

Ship's head S.W. = S. 45° W. R.
Dev. on S.W. 9 E. R.

Greater course S. 54° W.

Diff. between deviations, 2°

$$13\overline{)6}(0°$$
$$\underline{60}$$
$$13\overline{)360}(23′$$
$$\underline{26}$$
$$100$$
$$\underline{104}$$

(call it half a degree to add to 7° E.)

Distance to steam from position where repairs were finished, 37 miles.
Time occupied in steaming, 37 miles, at 10 knots, is 3h. 42m.

Time repairs were finished, . . 11h. 15m. A.M.
Steaming time to destination, . . 3 42

Time of arrival, ... 14 57 or 2h. 57m. P.M.

Example for Exercise V.

(To be worked on English Channel Chart.)

Deviation Card II. (ship's head magnetic).

Ques. 1.—February 4th, 1925. Using latitude by dead reckoning 50° 23′ N., the longitude found by observation of a celestial body bearing 240° was 6° 41′ W. At the same time, which was one hour after high water at Dover, a corrected cast of the deep-sea lead gave 54 fathoms, gravel and shells. Set a compass course from this position to bring Lundy Island South Lt. bearing 000° distant 3 miles. Make allowance for 5° of leeway, the wind being strong from the N.N.W., and for the tide as indicated by the chart.

Find, also, the distance to steam and the time occupied in reaching the destination, the ship making a steady 14 knots.

Ques. 2.—Having passed Lundy Island, and being in a position with Morte Point bearing 150° distant 5 miles, set the course by compass to make Flat Holm Island Lt. dead ahead distant 3 miles. No leeway to be allowed, but the ebb tide was estimated to be setting 280° at 3 knots. Also, if the ship maintained a speed of 14 knots, find how long she will take to reach the destination.

Answer to Example V.

Ques. 1.—Looking under (*H*) in the table of tidal streams on the chart, we see that for the 5 hours between 1 and 6 hours after high water at Dover that the tide set in a **mean** direction of 208° ÷ 5 = 42, and at a **mean** rate of 16 ÷ 5 = 3 knots. The set and drift to be allowed is, therefore, N. 42° E. (true) at 3 knots.

True course from chart,	N. 60° E. R.
Leeway,	5 L.
True course to steer,	N. 55° E. R.
Corrected variation,	20 W. R.
Magnetic course,	N. 75° E. R.
Deviation,	13 W. R.
Compass course,	N. 88° E.
Distance to steam,	74 miles.
Time occupied,	5 hrs. 17 mins.

From Deviation Card.

Ship's head N. 67½° E. gives dev. 14° W.
Ship's head N. 78¾° E. gives dev. 12 W.

2
7½
11)15(1°

14)74(5 hours
70
4
60
14)240(17 minutes
14
100
98

Ques. 2.

True course,	N. 84° E. R.
Variation,	20 W. R.
Magnetic course,	N. 104° E.
	180
Magnetic course,	S. 76° E. L.
Deviation,	9 W. R.
Compass course,	S. 67° E.
Distance to steam,	52 miles.
Time occupied,	3 hrs. 43 minutes.

From Deviation Card.

Ship's head S. 67½° E. gives dev. 8° W.
Ship's head S. 79¾° E. gives dev. 9° W.

1
8½
11)8½(1°

14)52(3 hours.
42
10
60
14)600(43 minutes.
56
40
42

NOTES.

REDUCTION TO SOUNDINGS.

General Remarks.

Reduction to soundings is the name which is given to a method of finding the "height of the tide" at high or low water, or at any time in between the times of high and low water. Having found this, you may be asked to answer any practical questions relating to it. Amongst these there have been given :—

Find the correction to apply to the leadline before comparing it with the depth marked on the chart.

Find the depth of water, the depth on chart being given.

Find what water a ship would have under her keel, her draught being given.

Find what clearance a ship would have when passing over a shoal patch or crossing a bar or entering a harbour or dock.

Find a vessel's draught, the depth of water under her keel being given.

Also **to find the time** at which a given depth of water will occur at any place.

The elements necessary for **finding the height of the tide** are :—

The **interval from high or low water** at that particular time.
The **duration of the rise or fall** of the tide.
The **height of the mean tide level.**
The **half range of the tide.**

The elements necessary **for finding the time** when a given depth of water will occur are :—

The **duration of the rise** or fall of the tide.
The **height of the mean tide level.**
The **half range of the tide.**
The **depth marked on the chart.**

The **height of the tide** at any moment is the height of the water level above chart datum level.

The **rise of the tide** is the height of **high water level** above chart datum level.

The **mean tide level** is the height of the water level when it is half-way between high and low water. It is found, when the low water of the tide on which you are working is above datum, by adding together the height of the low water and the height of the high water and dividing the sum by two.

If the height of the low water is **below datum** it is found by subtracting the height of the low water from the height of the high water, and dividing the remainder by two.

An asterisk (*) placed against a height means that the height against which it is placed is below datum.

The **range of the tide** is the difference between the heights of the low water level and the high water level of any one particular tide. In other words, it is the amount which the tide rises from low to high water or falls from high to low water. The "half range" of the tide may be obtained by dividing the range by two, but it is helpful when learning how to work soundings to express it as follows :—

The **half range** of a tide is the difference in height between the height of the high water or the height of the low water, and the mean tide level at any place.

If you are working with an interval before or after **high water**, it is found by subtracting the height of the mean tide level from the height of the high water at that place.

If you are working with an interval before or after **low water**, it is found by subtracting the height of the low water at the place from the height of the mean tide

level when the low water is above datum, but by **adding them together** when the level of the low water is below datum.

The **duration of rise** is the time which the tide takes to rise from low to high water level.

The **duration of fall** is the time which the tide takes to fall from high to low water level.

The **interval from high water** is the interval of time which elapses between the time in the problem and the time of high water.

The **interval from low water** is the interval of time which elapses between the time in the problem and the time of low water.

If this interval is **after high water the tide is falling**, and when finding the mean tide level and duration of fall you must be careful to use the height and time of the low water which occurs **after** the high water which you have already copied down.

If the interval is **before low water the tide is falling**, and you must be careful to use the height and time of the high water which occurs **before** the low water which you have already copied down.

If the interval is **before high water the tide is rising**, and you must find the mean tide level and duration of rise by using the height and time of the low water which occurs **before** the high water which you have already copied down.

If the interval is **after low water the tide is rising**, and you must use the height and time of the high water which occurs **after** the low water which you have already copied down.

Spring rise is the difference between the levels of the datum of the chart and of mean high water springs.

Spring range is the difference between the levels of mean low water springs and mean high water springs.

When the datum of the chart is exactly mean low water springs, "spring rise and "spring range" are the same.

Neap rise is the difference between the levels of the datum of the chart and of mean high water neaps.

Neap range is the difference between the levels of mean low water neaps and mean high water neaps.

Mean rise is the difference between the levels of the datum of the chart and of mean high water.

Mean range is the difference between the levels of mean high water and mean low water.

Age of the tide is the number of days by which the date of the spring tide follows the date of the new or full moon. This varies in different parts of the earth, and sometimes on different coasts of the same country. It is given in Table I. in Part II. of the Tide Tables, and in this book.

The first thing to do when working a "Reduction to Soundings" is to find out (as you did when working Tides) whether the place given in the question is a **Standard Port.** If it is, it will be found in the "List of Standard Ports." If it is not, it is called a "Secondary Port," and will have to be worked by means of the "**tidal differences**," which are given in Part II. of Tide Tables, as explained later on.

The times given throughout the tide tables are reckoned from one midnight to the next, 00h. 00m. representing midnight, and 12h. 00m. representing noon.

High and low water are given in two separate columns, and each successive high and low water are not, therefore, always printed in the order in which they occur. For this reason you must be very careful when finding the duration of rise or fall, and the mean tide level. In Worked Example I., for instance, the time of

low water next following the 23h. 27m. time of high water on the 22nd is the one at 05h. 38m. on the 23rd, **but they are not printed next to each other in the tide tables.**

Also, the time of low water next **preceding** the 23h. 27m. high water on the 23rd, which is at 17h. 14m., is printed in the tables to the right of it—that is, **after it.** This kind of thing occurs frequently throughout the book.

STANDARD PORTS are those ports given in PART I. of the tide tables, and for which the times and heights of the tides are predicted.

SECONDARY PORTS are those ports for which the times and heights of the tide are **not** directly predicted. These are found by means of the TIDAL DIFFERENCES corresponding to each place, which are given in PART II.

High water time difference is the difference between the time of high water at the Standard port and the time of high water at the Secondary port.

Low water time difference is the difference between the time of low water at the Standard port and the time of low water at the Secondary port.

High water height difference is the difference between the height of high water at the Standard port and the height of the high water at the Secondary port.

Low water height difference is the difference between the height of the low water at the Standard port and the height of the low water at the Secondary port.

If the time and height of water is required off a place which is a Standard port it is copied down direct from the Prediction table in PART I. for that port, **and differences are never required or used.**

If the time and height of water is required off a place which is a Secondary port, they are found by copying down the time and height at the Standard port and applying the tidal differences to them. The name of the Standard port which must be used and the value of the differences to be applied are given in PART II. of the tide tables.

When applying the low water difference to the height of a low water which is **below datum** at the Standard port, **it must be applied the opposite way to its sign.** When the diff. is **greater** than the height of the low water below datum at the Standard port, and has to be subtracted because it has a plus sign, the height of the low water **must be taken from the diff.**, the remainder being the height of low water at the Secondary port **above** datum. (*See* Worked Example III.) If the diff. in a case of this kind is **less** than the height of the low water below datum, the height of the low water at the Secondary port is also below datum.

When the low water diff. (having a minus sign) is added to the low water below datum at the Standard port, the low water at the Secondary port will be that amount **more** below datum (*see* Worked Example VI.).

TIDAL DIFFERENCES TO BE USED.

TIMES AND HEIGHTS.

When all the differences are given, the times and heights of high and low water at a Secondary port are found by applying these differences to the times and heights given in the prediction table for the Standard port.

If one difference is bracketted under high water springs and neaps or low water springs and neaps, it is a mean difference, and should be used throughout the lunation.

TIMES ONLY.

If one difference is bracketted under high and low water springs and neaps, it is a mean difference, and should be used throughout the lunation.

If high water spring and neap differences only are given, they should also be used for low water springs and neaps.

If a high water spring difference only is given, this should be used for both high and low water throughout the lunation.

HEIGHTS ONLY.

If high water differences only are given, low water differences should be found, as follows :—

Low water spring difference = 0·0 feet (nothing).

Low water neap difference = high water spring difference — high water neap difference.

Spring tides are those tides which occur from 0 to 2½ days after the date of the new and full moon. There is generally about 14 days' interval between one set of spring tides and the next.

Spring tides rise higher, fall lower, and flow with greater velocity than neap tides. Neap tides occur about half-way between two sets of springs.

If you are working on a spring tide, **spring differences must be used.**

If you are working on a neap tide, **neap differences must be used.**

If the date of your question is in between the dates of springs and neaps, a proportionate allowance must be made for both time and height to obtain the correct differences. This is done in the same way as already explained in "Tides," and is as follows :—

Find the difference between the spring and neap differences, multiply it by the number of days by which your date differs from the date of the spring tide, and divide the product by 7. The result is a correction to apply to the spring difference, which must be added to the spring difference if the neap difference is larger, but subtracted from the spring difference if the neap difference is smaller. The result is the corrected difference.

When dealing with the spring and neap diffs., if one has a + sign and the other has a — sign, **the difference between them is found by adding them together.** When this is the case, **the correction must always be subtracted** from the spring diff. If the correction is smaller than the spring diff., the corrected diff. will have the same sign as the spring diff. If the correction is larger than the spring diff., **the spring diff. must be subtracted from the correction**, in which case the corrected diff. will be + if the spring diff. is —, but will be — if the spring diff. is +.

The moon's phases are given in Table IV. (*b*) in PART I. of the tide tables.

The age of the tide at any place is given in PART II. of the tide tables.

The dates of the spring tides are found by adding the age of the tide at the place you are off to the dates of the new and full moon.

EXAMPLES :—

Find the dates of the spring tides which occur during the month of May at Wick.

Date of full moon, .	May 8th	Date of new moon, .	May 22nd
Age of tide in days,	2	Age of tide in days, .	2
Date of spring tide,	10th	Date of spring tide,	May 24th

To find the number of days by which your date differs from the date of the spring tide

Find the number of days by which your date differs from the date of the **preceding** new or full moon, and subtract the age of the tide from it. Or,

Find the number of days by which your date differs from the date of the **following** new or full moon, and add the age of the tide to it. (The smaller interval should be chosen.)

The result is the number of days by which your date differs from the date of the spring tide. If it comes to 0, **you are working on a spring tide.**

To verify the foregoing examples we will presume that we want to find the number of days by which the dates of May 10th and May 24th differ from the dates of the spring tides.

Date of question,	May 10th	
Date of preceding full moon,	May 8th	
Days from preceding full moon,	2	
Age of tide (subtract),	2	days
Days from spring tide,	0	
Date of question,	May 24th	
Date of preceding new moon,	May 22nd	
Days from preceding new moon,	2	
Age of tide (subtract),	2	
Days from spring tide,	0	

Mean time at ship and Local Mean time are one and the same thing.

Standard time and Zone time are one and the same thing.

If mean time at ship is given in the question and standard time in the tide tables, the mean time at ship must be turned into standard time by applying a correction for longitude to it. This must be done before finding the interval from high or low water.

Inversely, **if the question asks you to find the mean time at ship,** the standard time which you obtain in the answer must be turned into mean time at ship by applying a correction for longitude to it in the opposite way.

The correction for longitude is the difference of longitude, expressed in time, between the longitude for which standard time is taken and the longitude of the place you are off.

If you are **turning mean time at ship into standard time** you must **add** the correction for longitude to the mean time at ship **if the place you are off is to the Westward** of the longitude for which standard time is taken, but subtract it from the mean time at ship if the place you are off is to the Eastward.

If you are **turning standard time into mean time at ship** you must subtract the correction for longitude from the standard time if the place you are off is to the Westward of the longitude for which standard time is taken, but add it to the standard time if the place you are off is to the Eastward.

Checking the Gauge Correction.

The gauge correction which you take from the diagram may be checked by means of the traverse table, as follows :—

With the angle (which you have calculated) as the course, and the half range in the distance column, the corresponding D. Lat. is the gauge correction.

Likewise, **when you want to find the angle** with which to calculate the time, by finding the half range in the distance column and the amount which the height of the tide is above or below mean tide level in the D. Lat. column, the corresponding course is the angle required.

Worked Example I.

Standard Port (Standard Time given).

1925.—July 23rd, find the depth of water at 01h. 27m. Standard time off Holyhead. Depth marked on the chart, 8 fathoms.

Instructions for Working.—Look in the "List of Standard Ports" for Holyhead, find the number of the page where the **prediction table for Holyhead** is given, and turn up to it. Having found the prediction table, be sure that you use the right month.

Pick out from the prediction table the time of H.W. or the time of L.W. **whichever is nearest to the time given in the question.** This will generally be one of those times given in the prediction table for the same day as the question, but **may** be on the day before or the day after the date of the question.

In this particular example the time in the prediction table which is nearest to the time in the question is the H.W. at 23h. 27m. on the 22nd, which is the day **before** the date of the question. Write it down exactly as shown in the working on page 226.

Write down the time in the question underneath it.

The difference between these two times (2 hours) is the interval from H.W. at which the height of the tide is required. This interval being **after** H.W., it must be named **"interval after H.W."**

Abreast of the time of H.W. taken from the prediction table write down its corresponding height, and subtract the **mean tide level** from it.

The mean tide level (M.T.L.) is the height of the water level when it is half-way between high and low water. It is found (as the tide is falling) by adding the height of the H.W. and the height of the following L.W. together and dividing the sum by two. The height of the H.W. is 15·1 feet and the height of the following L.W. is 1·1 feet, the M.T.L. is, therefore, 8·1 feet (see opposite).

Subtract this from the height of H.W. at Holyhead, the remainder is the **half range** or height above M.T.L., which comes to 7 feet.

Draw two vertical scales of feet (tide gauges), as shown on the opposite page. These must be long enough to indicate the "rise of the tide."

Draw a horizontal line at right angles to them to represent M.T.L., which is 8·1 feet. Mark it 0 on left-hand gauge.

Graduate the left-hand gauge to each foot **both upwards and downwards** from 0.

Put in a line to represent **chart datum level,** which is 8·1 feet below M.T.L.

Graduate the right-hand gauge **upwards only,** from 0 at chart datum level to the "rise of the tide," which is 15·1 feet.

Take the **half range** in the compasses, and with the point on the M.T.L. at 0 describe a semicircle on the left-hand gauge.

The level of the water at 2 hours after H.W. is obtained by finding a correction from the gauge and applying it to M.T.L.

The time of H.W. was 23h. 27m. on the 22nd, and the time of the following L.W. was 05h. 38m. on the 23rd. The tide, therefore, took 6h. 11m. to fall from high to low water. This is called the **"duration of fall."**

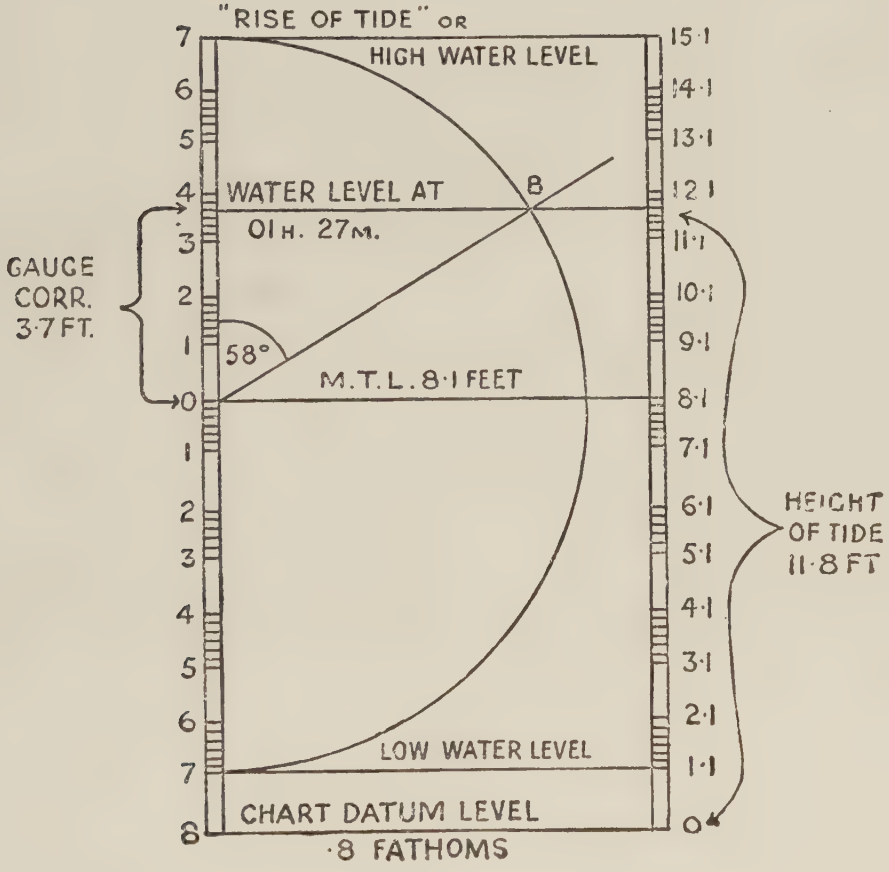
	Feet.
Height of H.W., . .	15·1
Height of L.W., . .	1·1
	2)16·2
Mean tide level, . .	8·1 feet.

	h.	m.	
Time of H.W., .	23	27	on 22nd
Time of L.W., .	05	38	on 23rd
Duration of fall, .	6	11	

The gauge correction is found as under :—

A straight line is drawn radiating from 0 on the left-hand gauge and cutting the semicircle at a point which indicates the level of the water at 2 hours after High water. The angle at which this line must be drawn is found by proportion.

DIAGRAM FOR WORKED EXAMPLE I.



WORKED EXAMPLE I.—*Continued.*

The duration of fall was 6h. 11m., we, therefore, say :—

As 6h. 11m. is to 2h. 0m., so is 180° to required angle,

or As 371m. is to 120m., so is 180° to required angle.

120
180
9600
120
371)21600(58°
1855
3050
2968

The angle of 58° is laid off from the **top** of the scale, because the interval of time is taken from **high water.** If it had been taken from **low** water, it would have been laid off from the **bottom** of the scale.

This line cuts the semicircle at *B*, and the horizontal line drawn through *B* indicates the water level at the time given in the question.

The distance between this horizontal line and the M.T.L. is shown by the gauge to be about 3·7 feet, and is the correction to add to the M.T.L., because the water level is higher than the M.T.L. The result is the " height of the tide " at two hours after H.W. This may be taken **direct** from the right-hand gauge.

By adding this to the depth marked on the chart we obtain the depth of water at that time.

	h.	m.		Feet.
Time of H.W. Holyhead, . .	23	27 on 22nd, Standard.	Height,	15·1
Time in question, . . .	01	27 on 23rd, Standard.	M.T.L.,	8·1
Interval after H.W., . .	2	0	Half-range,	7 0

		Feet.
M.T.L., . . .		8·1
Gauge corr., .	+	3·7
Height of tide, . .		11·8
Depth on chart, . .		48·0
Depth of water, . .		59·8 feet.
or 8 fathoms		11·8 feet.

Worked Example II.

Standard Port (Local Mean Time given).

1925.—**January 6th, at 00h. 50m. Local Mean time off Greenock, find the height of the tide and the depth of water where the chart indicated 9 fathoms. Required also, what water a vessel would have under her keel if her draught was 30 feet.**

Instructions for Working.—Local Mean time being given in the question, a **correction of longitude must be applied to it to turn it into Standard time** before it can be compared with the **Standard time** given in the Tide tables.

A correction for longitude must be applied in all examples in which Local mean time is given in the question and Standard time in the Tide tables. This applies equally the same whether you are working off a Standard port or a Secondary port.

The correction for longitude is the **difference in time** between the longitude of the place you are off and the longitude for which standard time is taken.

If the place you are off is to the **Eastward** of the longitude (or meridian), for which standard time is taken, **this correction must be subtracted** from the given local Mean time.

If the place you are off is to the **Westward** of the longitude for which Standard time is taken, **this correction must be added** to the given local Mean time.

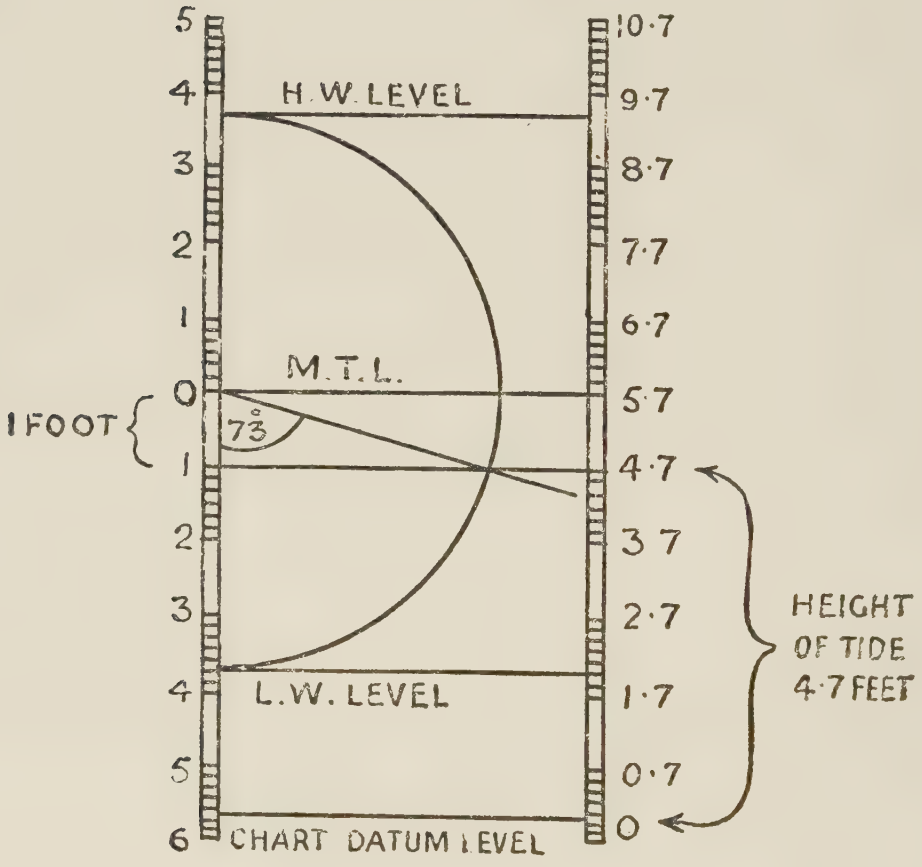
The Tide tables tell us that Greenock is in longitude 4° 46′ W., and that Standard time is mean time of the meridian of Greenwich. This makes the correction for longitude about 19 minutes to be added. As the Local mean time is 00h. 50m., the Standard time must be 01h. 09m., and this is the time which we write down underneath the Standard time taken from the Tide tables when we are finding the interval from High or Low water.

Turn up the prediction table for Greenock and pick out the time of the High or Low water **which is nearest** to 01h. 09m. on January 6th. This will be the Low water at 03h. 31m. on the 6th. Write it down, put the **Standard** time of the question underneath it, and find the interval (in this case) before Low water.

Copy down the corresponding height given abreast of it, which is 2·1 feet, and subtract it from the Mean tide level. The remainder is the **half range**, which is 3·6 feet.

The Mean tide level is the mean of the height of the Low water which we have just copied down and the height of the High water which occurs next before it. The High water **before** it is taken because the depth being required **before** Low water, the tide must be falling. Be careful to note that the High water which occurs next before our Low water is 9·3 feet at 21h. 43m. on the 5th, but that **it is not printed next before it** in the Tide tables.

DIAGRAM FOR WORKED EXAMPLE II.



WORKED EXAMPLE II.—*Continued.*

Likewise, the **duration of fall** is the interval of time which elapses between the High water at 21h. 43m. on the 5th and the Low water at 03h. 31m. on the 6th, which is 5h. 48m.

	Feet.		h.	m.	
Height of H.W., . .	9·3	Time of H.W., .	21	43	on 5th
Height of L.W., . .	2·1	Time of L.W., .	03	31	on 6th
	2)11·4	Duration of fall,	5	48	
Mean tide level, . .	5·7 feet.				

Draw the diagram and finish the problem in the same way as in Worked Example I.

The angle at which to draw the line radiating from the Mean tide level at 0 is found as shown below. It is laid off from the **bottom** of the diagram, because the interval occurs before **low water.**

As 5h. 48m. : 2h. 22m. :: 180° : x,
or As 348m. : 142m. :: 180 : x.

142
180
11360
142
348)25560(73°
2436
1200
1044

	h.	m.			Feet.
Time of L.W. Greenock, .	03	31	Standard	Height, .	2·1
Time of question, . . .	01	09	Standard	M.T.L., .	5·7
Interval before L.W., . .	2	22		Half range, .	3·6

	Feet.
M.T.L., ...	5·7
Gauge corr. . .	— 1·0
Height of tide, . .	4·7
Depth on chart, . .	54·0
Depth of water, . .	58·7
Ship's draught, . .	30·0
Water under keel, . .	28·7
or 4 fathoms	4·7

Worked Example III.

Secondary Port (All Differences given—Spring Tide).

1925.—July 7th, at 10h. 20m. Standard time, find the depth of water at the conical buoy off the entrance to Shoreham, the depth marked on the chart being 14 feet.

Instructions.—Look in the List of Standard Ports for Shoreham. You will not find it there. You consequently know that it is not a Standard port, and that it will be found in Part II. of the Tide Tables.

Look in the Index to Part II., turn up to Shoreham and copy the differences down in the margin, also the name of the Standard port, which is Dover.

You must now find out whether the date of your question is on a spring or a neap tide, and if not, by **how many days it differs** from the date of the spring tide.

Turn up Part II. of the Tide Tables, and look in Table I., headed "Age of the tide," for the locality in which Shoreham is situated. Being in the English Channel (South Coast of England), you will see that the "Age of the tide" for that place is 1½ days.

Turn back to Part I., and look in the table headed **Moon's Phases, Declination, etc.**, and find the date of the new or full moon which is nearest to the date of your question (July 7th). The nearest new or full moon is the **preceding full moon** on July 6th, which is one day different from the date of the question.

As previously explained in General Remarks, you must subtract the age of the tide from this number of days. Subtracting one and a half days (call it one day) from one day leaves nothing. The date of your question, therefore, differs nothing from the date of the spring tide. In other words, **you are working on a spring tide,** for which reason spring differences must be used throughout.

Turn to the prediction table for Dover, and pick out the time of high or low water which (after the difference has been applied) is nearest to your given time.

Standard time being given in the Tide Tables, and also in the question, **a correction for longitude is not required.**

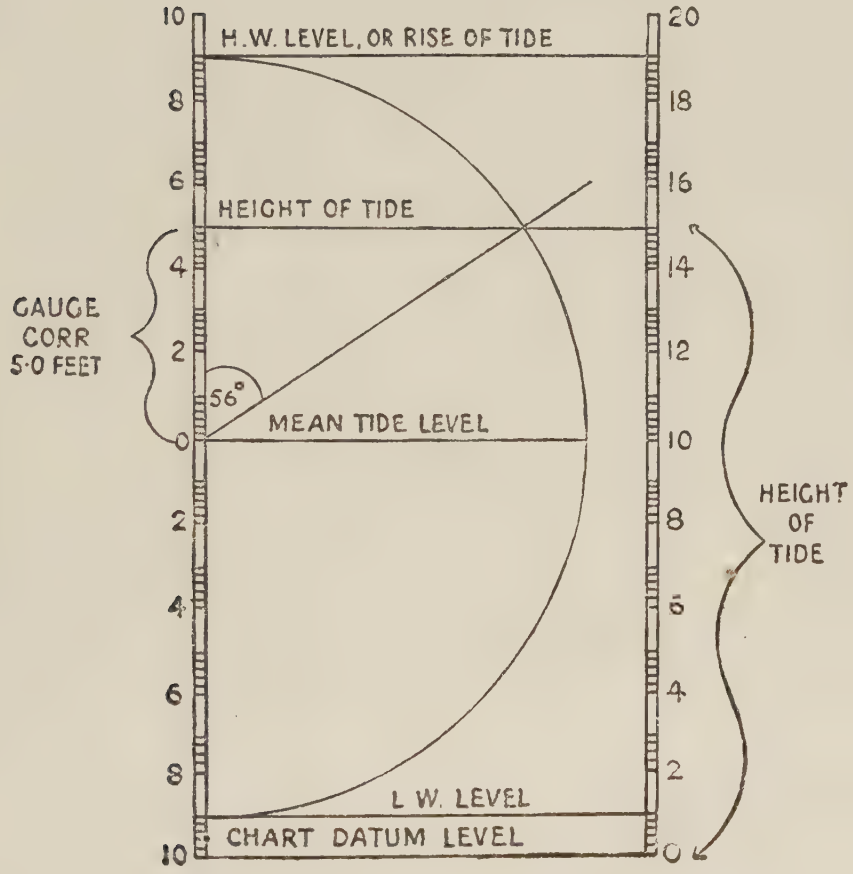
The nearest tide is the high water at 11h. 44m. Copy it down and apply the high water spring difference to it. This will give you the time of high water at Shoreham, which is 12h. 04m., and which makes the interval before high water 1h. 44m.

The height of the 11h. 44m. tide is 19·2 feet. Copy it down abreast of the time as shown on the opposite page and apply the high water spring difference to it. This gives you the height of the tide at Shoreham, which is 19·0 feet. Subtract the mean tide level from it; the remainder is the "half range."

The mean tide level is found as follows:—

	Feet.		Feet.	Feet.
Height of L.W. Dover,	0·4*	Height of H.W. Dover,	19·2	L.W., 1·1
L.W. diff. + (subtracted)	1·5	H.W. diff. —	0·2	H.W., 19·0
Height of L.W. Shoreham,	1·1	Height of H.W. Shoreham,	19·0	2)20·1
				Mean tide level, 10·0

Diagram for Worked Example III.



WORKED EXAMPLE III.—*Continued.*

Find the duration of rise, calculate the angle, draw the diagram, and finish as in previous examples.

The duration of rise is found as follows :—

	h.	m.		h.	m.		h.	m.
Time of L.W. Dover, .	06	53	Time of H.W. Dover, .	11	44			
L.W. diff. — . .	0	24	H.W. diff. + . .		20	L.W.,	06	29
						H.W.,	12	04
Time of L.W. Shoreham,	06	29	Time of H.W. Shoreham,	12	04			
						Duration of rise,	5	35

TIME DIFFS.

	h.	m.
H.W. Sp. +	0	20
H.W. Np. +	0	05
L.W. Sp. —	0	24
L.W. Np. —	0	39

HEIGHT DIFFS.

	Feet.
H.W. Sp. —	0·2
H.W. Np. —	0·6
L.W. Sp. +	1·5
L.W. Np. —	0·1

Standard Port, Dover.

	h.	m.			Feet.
Time of H.W. Dover, .	11	44	Standard	Height Dover, .	19·2
H.W. diff. . . +		20		H.W. diff. . —	0·2
Time of H.W. Shoreham,	12	04	Standard	Height Shoreham,	19·0
Time in question, . .	10	20	Standard	M.T.L., . .	10·0
Interval before H.W., .	1	44		Half range, . .	9·0

To find the angle.

As 5h. 35m. : 1h. 44m. : : 180° : x
or as 335m. : 104m. : : 180° : x

104
180
8320
104
335)18720(56°
1675
1970
2010

	Feet.
M.T.L., . . .	10·0
Gauge corr. . +	5·0
Height of tide, .	15·0
Depth on chart, .	14·0
Depth of water, .	29·0

Worked Example IV.

Secondary Port (Local Mean Time given).

$4\frac{1}{2}$ Days from Springs.

1925.—October 14th, at 04h. 16m. Local Mean time off Whitehaven, find the depth of water in a position where the chart indicates 21 feet.

Instructions.—Look in Table I., Part II., of the Tide Tables, and find the age of the tide at Whitehaven, which is $1\frac{1}{2}$ days.

Turn back to Part I., look in the table headed "**Moon's Phases, Declination, etc.,**" and find the date of the new or full moon which is nearest to the date of your question. The nearest one is the **following new moon** on October 17th, which is 3 days different from the date of your question.

As previously explained in General Remarks, you must **add** the age of the tide to this number of days, which gives $4\frac{1}{2}$ days as the interval by which your date differs from the date of the spring tide.

The differences must be corrected for this $4\frac{1}{2}$ days.

The L.W. time differences not being given, the H.W. time differences have also to be used for low water. There is consequently only one correction to be made to the **time** differences. It is done as under :—

Time Diffs.	h.	m.
H.W. Sp.	− 0	01
H.W. Np.	+ 0	05
L.W. Sp.	...	
L.W. Np.	...	

Height Diffs.	Feet.
H.W. Sp.	− 3·0
H.W. Np.	− 2·2
L.W. Sp.	+ 0·8
L.W. Np.	+ 0·4

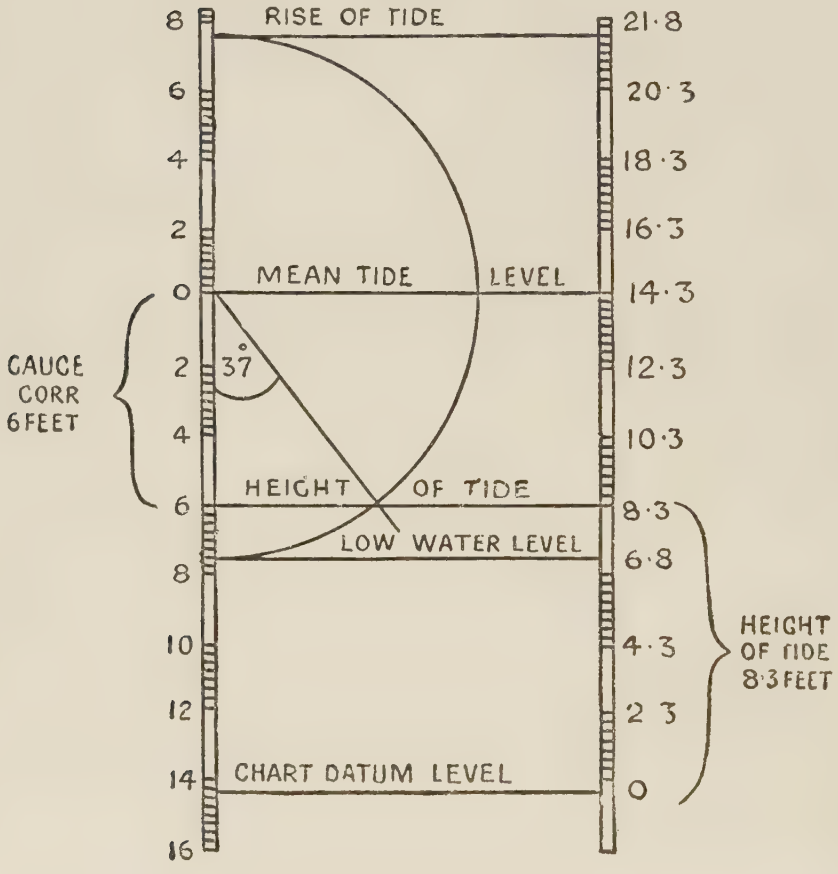
Standard Port, Liverpool.

		h.	m.
High water spring difference, . .	−	0	01
High water neap difference, . .	+	0	05
Difference between spring and neap diffs., .		0	6
Multiply by interval from spring tide, .		0	4·5 days
Divide by seven days, . . .		7)27·0	
Correction to subtract from spring difference,			4
High water spring difference, . .	−	0	1
Corrected high water time difference,	+	0	3

Both height differences have to be corrected. The working is as follows :—

High water spring difference, ...	− 3·0 feet
High water neap difference, ...	− 2·2 feet
Difference between spring and neap diffs., . . .	·8 feet
Multiply by interval from spring tide, ...	4·5 days
Divide by seven days, ...	7)3·60
Correction to subtract from spring diff., . . .	·5 feet
High water spring difference, ...	− 3·0 feet
Corrected high water difference, ...	− 2·5 feet
Low water spring difference, ...	+ 0·8 feet
Low water neap difference, ...	+ 0·4 feet
Difference between spring and neap diffs., . . .	·4 feet
Multiply by interval from spring tide, ...	4·5 days
Divide by seven days, ...	7)1·80
Correction to subtract from spring diff., . . .	·3 feet
Low water spring difference, ...	+ 0·8 feet
Corrected low water difference, ...	+ 0·5 feet.

Diagram for Worked Example IV.



WORKED EXAMPLE IV.—*Continued.*

As Local Mean time is given in the question, and Standard time in the Tide Tables, **we must apply a correction for longitude** to the Local Mean time to turn it into Standard time. It is found as under :—

Standard time is for longitude, . . .	0° 0′
Whitehaven is in longitude, ...	3 36 W.
Difference of longitude, ...	3 36
	4
Correction for longitude, ...	14m. 24s.

As Whitehaven is to the Westward of the longitude for which Standard time is taken, this correction of 14m. must be added to the given Local Mean time of 4h. 16m., which makes the corresponding Standard time 04h. 30m.

To find the duration of rise.

Time L.W. Liverpool, .	03h. 15m.	Time H.W. Liverpool,	09h. 01m.		
L.W. difference, . +	3	H.W. difference, +	3	L.W., .	03h. 18m.
Time L.W. Whitehaven,	03 18	Time W.H. Whitehaven,	09 04	H.W., .	9 04
				Duration of rise,	5 46

To find the mean tide level.

Hgt. L.W. Liverpool, .	6·3 feet.	Hgt. H.W. Liverpool,	24·3 feet.	L.W.,	6·8 feet.
L.W. difference, . +	0·5	H.W. difference, —	2·5	H.W.,	21·8
Hgt. L.W. Whitehaven,	6·8	Hgt. H.W. Whitehaven,	21·8		2)28·6
				Mean tide level,	14·3

Time L.W. Liverpool, .	03h. 15m.	Standard	Hgt. Liverpool, . .	6·3 feet.	
Corrected L.W. diff. +	3		Corr. L.W. diff. . +	·5	
Time L.W. Whitehaven,	03 18	Standard	Hgt. Whitehaven, .	6·8	
Time of question, .	04 30	Standard	Mean tide level, . .	14·3	
Interval after L.W., .	1 12		Half range, . .	7·5	

To find the angle.

As 5h. 46m. : 1h. 12m. : : 180° : x
or as 346m. : 72m. : : 180° : x

72
180

5760
72

346)12960(37°
1038

2580
2422

M.T.L., . . .	14·3 feet.
Gauge corr. .	— 6·0
Height of tide, .	8·3
Depth on chart, .	21·0
Depth of water, .	29·3 feet.

Worked Example V.

Secondary Port (Local Mean Time given).

No low water differences. Neap tide.

1925.—October 12th, at 14h. 30m. Mean time at ship, find the depth of water off Nieuport, Belgium, in a position where the chart indicated 16 feet.

In this, **and in all problems** when you are working off a Secondary port, you must find out if the question is set on a spring or a neap tide, and if not, **by how many days it differs** from the date of the spring tide.

Turn up Part II. of the Tide Tables, and copy down the age of the tide at Nieuport. Being on the coast of Belgium, you will see that it is $2\frac{1}{2}$ days.

Turn back to Part I. and find, in the table headed "**Moon's Phases, Declination, etc.,**" the date of the new or full moon which is nearest to the date of your question. The nearest one is the **following new moon** on October 17th. Your question being dated the 12th, there is an interval of five days between them. The age of the tide must be **added** to this interval, this gives $7\frac{1}{2}$ days, which is the number of days by which your date differs from the date of the spring tide.

As there is an interval of about seven days between spring and neap tides, **you must be working on a neap tide and must use neap differences throughout.**

In this example, **the high water spring difference only** is given for times. That being the case, it must be used for both high and low water springs and neaps—that is, **for all tides** throughout the lunation.

Also, **the high water differences only** are given for heights. That being the case :—

The low water spring difference = 0·0 feet (nothing).

The low water neap difference = H.W. spring diff. — H.W. neap diff. (Write it down as shown two pages on.)

Standard time being given in the Tide Tables and Mean time at ship (which is the same as Local Mean time) in the question, **a correction for longitude must be applied** to the Mean time at ship to turn it into Standard time. Nieuport being to the Westward of the longitude, for which Standard time is taken, this correction must be added.

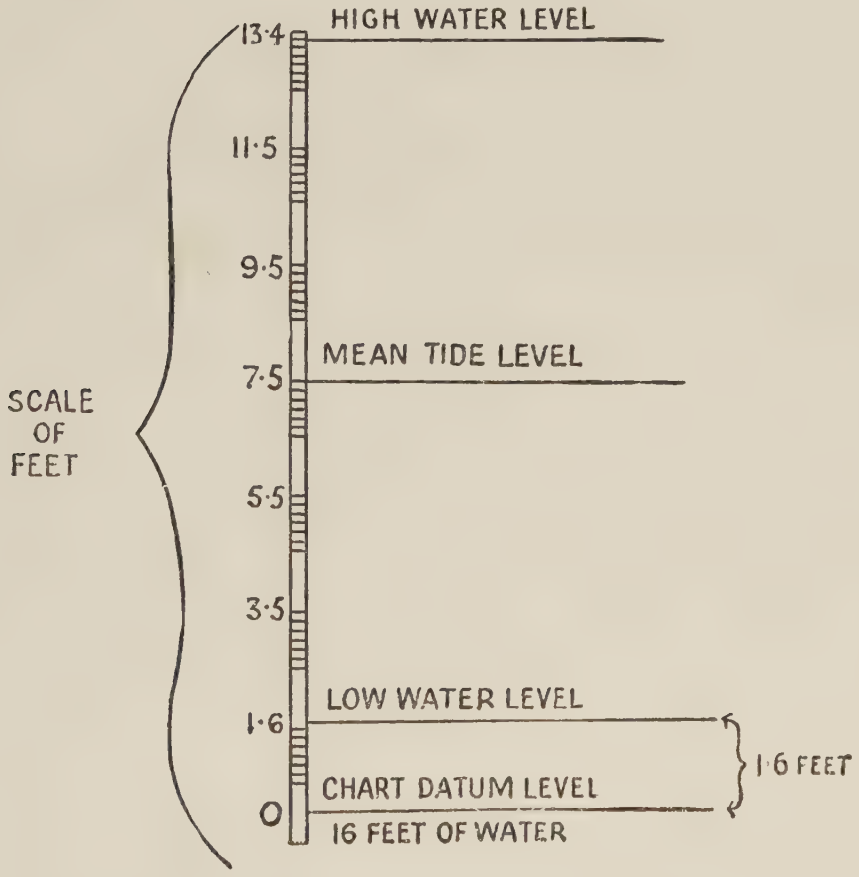
Turn up the prediction table for Flushing and copy down the time of high or low water which is nearest (after the difference has been applied) to the time given in the question. This is the low water at 15h. 54m. When you have applied the low water neap difference to it (the high water spring diff. must be used), you will find that the time of the question exactly coincides with the time of low water.

The height of the low water (height of the tide) added to the depth marked on the chart, therefore, represents the depth of water asked for in the question. There is no angle to calculate.

A diagram is not necessary, but it has been drawn to make the explanation clearer.

The mean tide level used is that between the height of this particular low water and that of the following high water. Had the height of the preceding high water been used, the mean tide level would have been 7·05 feet, making the diagram slightly different though the answer to the question would be the same.

Diagram for Worked Example V.



WORKED EXAMPLE V.—*Continued.*

Age of tide, 2½ days.

Date of question, . . Oct. 12th
Date of following new moon, Oct. 17th

Interval from following new moon, 5 days
Age of tide, ... 2½ days

Interval from spring tide, . . 7½ days

High water spring difference, . . + 2·7 feet
High water neap difference, . . + 2·5 feet

Low water neap difference, . . + 0·2 feet

Standard time is for longitude, . . 4° 53′ E.
Nieuport is in longitude, . . . 2 44 E.

Difference of longitude, . . . 2 9
4

Correction for longitude, . . . 8m. 36s. to add

	h.	m.
Mean time at ship given in question . .	14	30
Correction for longitude, . . . +		9
Standard time of question, ...	14	39

TIME DIFFS.

	h.	m.
H.W. Sp.	− 1	15
H.W. Np.	...	
L.W. Sp.	...	
L.W. Np.	...	

HEIGHT DIFFS.

	Feet.
H.W. Sp.	+ 2·7
H.W. Np.	+ 2·5
L.W. Sp.	...
L.W. Np.	...

Standard Port, Flushing

To find the mean tide level.

	Feet.		Feet.		Feet.
Hgt. L.W. Flushing, .	1·4	Hgt. H.W. Flushing, .	10·9	L.W., .	1·6
L.W. neap diff. .	+0·2	H.W. neap diff. +	2·5	H.W., .	13·4
					2)15·0
Hgt. L.W. Nieuport, .	1·6	Hgt. H.W. Nieuport, .	13·4		
				Mean tide level, .	7·5

	h.	m.		Feet.
Time L.W. Flushing, .	15	54	Standard	Hgt. L.W. Flushing, 1·4
L.W. neap diff. . —	1	15		L.W. neap diff. + 0·2
Time L.W. Nieuport, .	14	39	Standard	Hgt. L.W. Nieuport, 1·6
Time of question, .	14	39	Standard	Mean tide level , . 7·5
Interval from L.W., .	0	0		Half range, . . 5·9

Height L.W. Nieuport, 1·6 feet
Depth on chart, . 16·0 feet

Depth of water, . 17·6 feet

Worked Example VI.

Secondary Port (Spring Tide—Below Datum).

1925.—September 4th, off Silloth, where the chart shows 26 feet, find the height of the tide and the depth of water at 06h. 56m. Mean time at Greenwich.

Mean time at Greenwich and Standard time in this question are one and the same thing.

Find the age of the tide from Part II. of the Tide Tables.

Find the number of days by which the date of your question differs from the date of the spring tide. The working on the opposite page shows this to be only half a day, you may, therefore, say that you are working on a spring tide.

This may be verified by adding the age of the tide (call it two days) on to the date of the full moon, which is September 2nd. This gives us September 4th as the date of the spring tide. Being also the date of the question, it agrees with the above statement.

As we are working on a spring tide, **spring differences must be used throughout.**

As the tide is falling at the time given in the question, we must find the duration of fall, also the mean tide level.

The high water spring difference only being given for the times, it must be used for both high and low water. Note when finding the duration of fall, that a blank (—) occurs in the H.W. column on the 4th, and that the preceding high water is at 23h. 49m. on the 3rd.

To find the duration of fall.

		h.	m.			h.	m.		h.	m.
Time H.W. Liverpool,	.	23	49 on 3rd	L.W. Liverpool,	.	06	52			
H.W. spring diff.	+	0	25	L.W. spring diff.	+	0	25	H.W., .	00	14
								L.W., .	07	17
Time H.W. Silloth,	.	00	14	L.W. Silloth,	.	07	17			
								Duration of fall,	7	3

As both spring differences are given for the heights, they are used as given.

To find the mean tide level.

		Feet.			Feet.		Feet.
Hgt. H.W. Liverpool,	.	31·0	Hgt. L.W. Liverpool,	.	0·3 *	H.W., .	28·1
H.W. spring diff.	—	2·9	L.W. spring diff.	—	·9	L.W., .	1·2 *
			(added)				2)26·9
Hgt. H.W. Silloth,	.	28·1	Hgt. L.W. Silloth,	.	1·2 *	Mean tide level,	13·5

The height of the low water at Liverpool being below datum, the low water difference **is applied the opposite way to its sign**, making the height of the low water at Silloth 1·2 feet below datum.

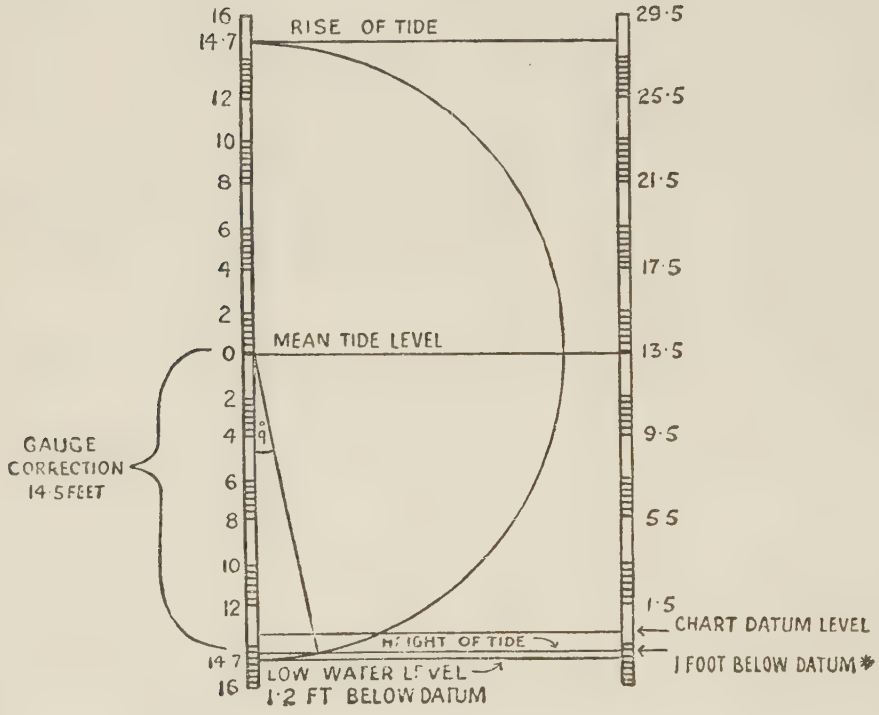
The height of the low water being below datum, it is subtracted from the height of the high water when finding the mean tide level.

Having calculated the angle to be 9°, and laid off the straight line from 0 towards the bottom of the diagram, we find that it cuts the semicircle below chart datum level. This shows us that the water level at the time in the question (the height of the tide) was below the datum level of the chart.

The **distance** which it is below the datum level is found by subtracting the mean tide level from the gauge correction, which gives us one foot. This makes the depth of water one foot **less** than that shown on the chart.

This gauge correction may be taken approximately from the diagram or found from the Traverse Table, as previously explained under " General Remarks."

DIAGRAM FOR WORKED EXAMPLE VI.



Worked Example VI.—*Continued.*

Time Diffs.

	h.	m.
H.W. Sp.	+ 0	25
H.W. Np.	...	
L.W. Sp.	...	
L.W. Np.	...	

Height Diffs.

	Feet.
H.W. Sp.	— 2·9
H.W. Np.	— 1·4
L.W. Sp.	— 0·9
L.W. Np.	— 1·3

Liverpool.

Date of the question is September 4th
Preceding full moon is on September 2nd

Days from preceding full moon, . . 2
Age of tide (subtract), . . . 1½ days

Number of days from spring tide, . 0½

Copy down from the prediction table the time of high or low water which is nearest to the time given in the question, together with its height. Find the interval from L.W. and the half range; also the angle proportionate to the time from low water.

Finish off as shown below.

	h.	m.		Feet.
Time L.W. Liverpool,	06	52	Hgt. Liverpool, . .	0·3 *
L.W. spring diff. +	0	25	L.W. sp. diff. .	— 0·9
Time L.W. Silloth,	07	17	Hgt. Silloth, . .	1·2 *
Time in question, .	06	56	M.T.L., . . .	13·5
Interval before L.W.,	0	21	Half range, . . .	14·7

As 7h. 3m. : 0h. 21m. : : 180° : x
or as 423m. : 21m. : : 180° : x

21
180

1680
21

423)3780(9°
3807

Mean tide level, . .	13·5 feet
Gauge correction, .	14·5 feet
Height of tide, . .	1·0 *
Depth on chart, . .	26·0 feet
Depth of water, . .	25·0 feet

Worked Example VII.

Standard Port (Standard Time).

To find the time when there is a given depth of water.

1925.—**Off Sheerness during the first watch on the night of July 5th, find the Standard time at which there will be 5 fathoms of water on a shoal patch where the chart indicates 3 fathoms.**

This question is somewhat different from the preceding ones. **We have to find the time** at which there will be a given depth of water.

A vessel often having to wait until there is enough water for her to cross a bar or enter a harbour or dock, it may be said to be a practical and useful one.

It should be worked in the following order :—

Find the time which the tide takes to rise from L.W. to the H.W. next following the time (or during the period of time) given in the question.

In this example the low water we must use is the one at 17h. 53m., and the following high water is the one at 00h. 04m. on the 6th. The interval between these two times is 6h. 11m., and is called, as in other examples, the **duration of rise.**

Find the mean tide level. The mean tide level is the level of the water when it is midway between the heights of these two tides. It comes to 9·0 feet.

Find the half range of the tide. This is done by subtracting the height of the low water from the height of the mean tide level. It comes to 8·0 feet. The same result is obtained by subtracting the mean tide level from the height of the high water.

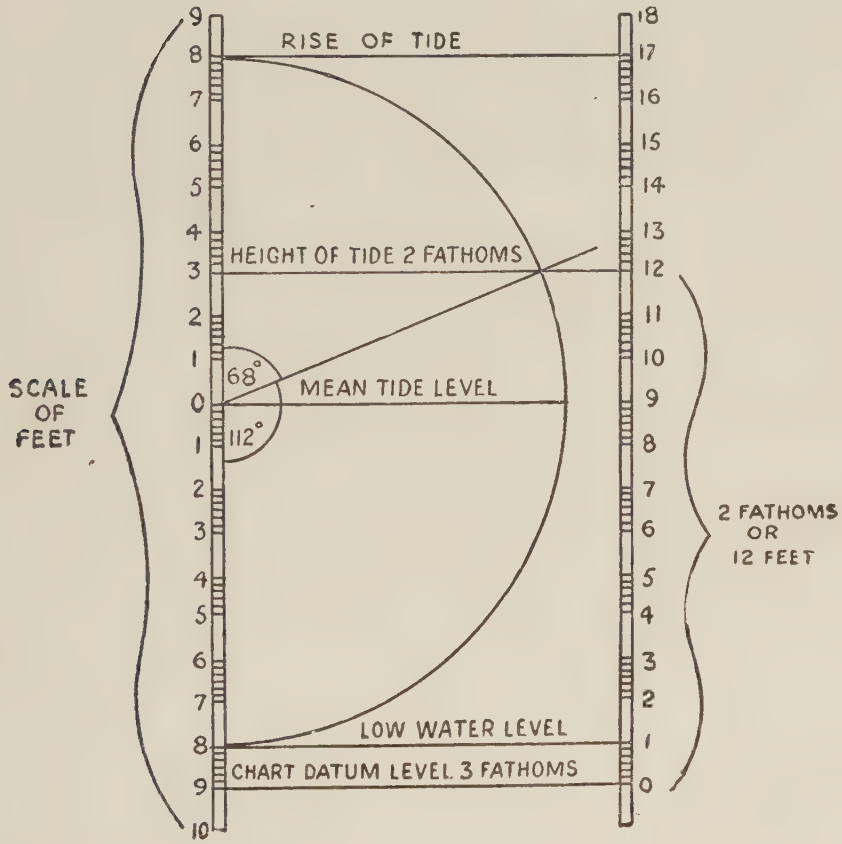
Draw the diagram, graduate the scales (tide gauges) to feet, and with the half range in the compasses describe the semicircle as in the preceding examples. Put the chart datum level in. The mean tide level being 9·0 feet, the chart datum level must be 9 feet below it.

	h.	m.	
Time L.W. Sheerness, .	17	53	on 5th
Time H.W. Sheerness, .	00	04	on 6th
Duration of rise, . .	6	11	

	Feet.
Hgt. L.W. Sheerness, .	1·0
Hgt. H.W. Sheerness, .	17·0
	2)18·0
Mean tide level, . .	9·0

	Feet.
Hgt. L.W. Sheerness, .	1·0
Mean tide level, . .	9·0
Half range, . .	8·0

DIAGRAM FOR WORKED EXAMPLE VII.


RISE OF TIDE
HEIGHT OF TIDE 2 FATHOMS
MEAN TIDE LEVEL
LOW WATER LEVEL
CHART DATUM LEVEL 3 FATHOMS
68°
112°
SCALE OF FEET
2 FATHOMS OR 12 FEET
9 8 7 6 5 4 3 2 1 0 1 2 3 4 5 6 7 8 9 10
18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0

WORKED EXAMPLE VII.—*Continued.*

As we want to find the time when the water will be 2 fathoms higher than the 3 fathoms shown on the chart (chart datum level), we draw a horizontal line across the diagram at a height of 2 fathoms (12 feet) above chart datum level. We must now find how long the tide will take to rise from low water level to the level of this line.

Draw a straight line from 0 on the left-hand gauge passing through the point where the horizontal line cuts the semicircle.

By means of a protractor find the angle which this line makes with the left-hand tide gauge. Counting from the bottom, you will find that it is about 112°.

By means of this angle and the **duration of rise** we find the time which the tide takes to rise from low water level to the given level of 2 fathoms above chart datum level. This is done by proportion.

The duration of rise is 6h. 11m., we, therefore, say :—

As 180° : 112° : : 6h. 11 m. : x
or as 180° : 112° : : 371 m. : x

371
112
742
371
371
180)41552(231 mins., or 3h. 51m.
360
555
540
152

	h.	m.
The time of L.W. when the depth was 3 fathoms was . .	17	53
To rise to 2 fathoms above chart datum the tide took . .	3	51
There will be 5 fathoms of water at	21	44

By using the top angle of 68° we can find the time which the tide will take to reach high water level from the 5 fathoms level. By subtracting this from the time of high water we get the same result.

As 180° : 68° : : 6h. 11m. : x
or as 180° : 68° : : 371m. : x

371
68
2968
2226
180)25228(140 mins., or 2h. 20m.
180
722
720
28

	h.	m.	
The time of H.W. was	00	04	on 6th
To rise from 5 fm. level to H.W. the tide will take . .	2	20	
There will be 5 fathoms of water at	21	44	

Worked Example VIII.

Secondary Port (Mean Time at Ship).

1925.—In Rye Bay, during the evening of June 4th, find the Mean time at ship when there will be one fathom more water than is shown on the chart.

Copy the given differences down in the margin as shown on the opposite page.

Begin the working by finding the number of days by which the date of your question differs from the date of the spring tide. You will find it to be $3\frac{1}{2}$ days.

The next thing is to correct the differences.

The high water time differences only being given, they must also be used for low water. The date of the question being $3\frac{1}{2}$ days from springs, which is midway between springs and neaps, the mean of the spring and neap differences must be used. This gives us + 0h. 14m. as the correct difference for both high and low waters.

The correct high water height difference will be the mean of the H.W. spring and H.W. neap differences, which is + 4·7 feet.

The high water height differences only being given, the L.W. spring diff. = 0·0 feet. The L.W. neap diff. = H.W. spring diff. − H.W. neap diff., which is + 0·8 feet.

The correct low water height difference will be the mean of the L.W. spring and L.W. neap differences, which is + 0·4 feet.

Pick out from the Prediction Tables for Dover the times of L.W. and H.W. which occur during the time given in the question (evening of June 4th), and **find the duration of rise.** Allowance must be made for the differences, because we want the duration of rise at Rye Bay, not at Dover. In this particular example they are both of the same value, and it would consequently not make any difference if they were missed out. They are put down on the opposite page to show the form. More often they are not both the same, in which case they **must** be used.

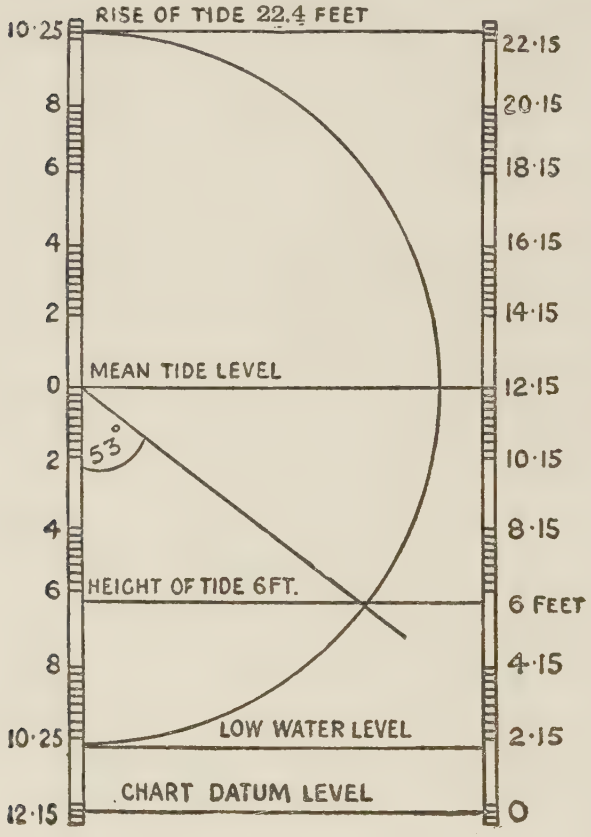
Find the mean tide level and the half range.

Draw the diagram. The position of the chart datum level line is found by measuring the amount of the mean tide level downwards from 0 on the left-hand gauge.

Describe the semicircle, using, as in all cases, the half range of the tide as radius.

Hgt. L.W. Rye Bay,	1·9 feet
Hgt. H.W. Rye Bay,	22·4 feet
Range of tide, .	20·5
Half range, . .	10·25 feet

DIAGRAM FOR WORKED EXAMPLE VIII.



WORKED EXAMPLE VIII.—*Continued.*

Age of tide, . . . 1½ days
Date of full moon, . . 6th

Date of spring tide, June, . 7½ days

Date of question, June 4th
Following full moon, June 6th

Days from full moon, 2
Age of tide, . . 1½

Days from spring tide, 3½

TIME DIFFS.

	h.	m.
H.W. Sp	+ 0	10
H.W. Np.	+ 0	18
L.W. Sp.	...	
L.W. Np.	...	

	h.	m.
L.W. Dover, .	16	18
L.W. diff. +	0	14
L.W. Rye Bay,	16	32

	h.	m.
H.W. Dover, .	21	19
H.W. diff. +	0	14
H.W. Rye Bay,	21	33

	h.	m.
L.W.,	16	32
H.W.,	21	33
Duration of rise,	5	1

HEIGHT DIFFS.

	Feet.
H.W. Sp.	+ 5·1
H.W. Np.	+ 4·3
L.W. Sp.	...
L.W. Np.	...

	Feet.
L.W. Dover, .	1·5
L.W. diff. +	0·4
L.W. Rye Bay,	1·9

	Feet.
H.W. Dover, .	17·7
H.W. diff. +	4·7
H.W. Rye Bay,	22·4

	Feet.
L.W.,	1·9
H.W.,	22·4
	2)24·3
Mean tide level,	12·15

As we want to find the time at which there will be 6 feet more water than is shown on the chart, we draw a horizontal line across the diagram at a height of 6 feet above chart datum level.

If we find how long the tide will take to rise from low water level to the level of this line, and add this on to the standard time of low water at Rye Bay, we shall have the standard time at which there is 6 feet more water than is shown on the chart.

As the question asks for mean time at ship, a correction for the longitude must be applied. See bottom of page.

Draw a straight line from 0 on the left-hand tide gauge, making it pass through the point where the horizontal line cuts the semicircle.

By means of a protractor take off the angle which this line makes with the left-hand tide gauge. You will find that it is about 53°.

With this angle and the duration of rise we find the time which the tide takes to rise from low water level to the level of 6 feet above chart datum level. This is done by proportion.

The duration of rise was 5h. 1m., we therefore say :—

As 180° : 53° : : 5h. 1m. : x
or as 180° : 53° : : 301m. : x

$$\begin{array}{r} 301 \\ 53 \\ \hline 903 \\ 1505 \\ \hline 180)15953(89\text{m., or 1h. 29m.} \\ 1440 \\ \hline 1553 \\ 1620 \end{array}$$

	h.	m.	
The time of low water at Rye Bay was . . .	16	32	Standard
To rise to 6 feet above chart datum the tide took .	1	29	
There will be one fathom more water at . . .	18	01	Standard
Correction for longitude (E. add), ...		3	
	or 18	04	M.T. ship

Standard time is for longitude, . . .	0°	0′
Rye Bay is in longitude, ...	0	45 E.
Difference of longitude, ...	0	45 = 3 minutes of time

Worked Example IX.

Standard Port. (Standard time given.)

1925.—September 2nd, off Wellington, New Zealand, find the depth of water at 13h. 21m. Standard time in a position where the depth of water marked on the chart is 6 fathoms.

Instructions for working.—Look in the "List of Standard Ports" for Wellington, turn to the number of the page where the predictions for Wellington are given, take out and write down the time of High or Low water which is nearest to the time given in the question.

Write down underneath it the time given in the question. The difference between these two times is the interval from H.W. or L.W., whichever is used. In this case, as we have used H.W. it is the interval from H.W., and as the time in the question precedes the time given in the Tide Tables we name it "Interval *before* high water."

Copy down the height of the H.W. corresponding to the time previously chosen, and as the time in the question is *before* H.W. the tide is rising, so we put down underneath it the height of the *preceding* L.W. The difference between these two heights is the "range of the tide." Divide this by two to get the "half range." Subtract the half range from the height of the H.W. to get the mean tide level (M.T.L.).

Now copy down the time of H.W. again, and (as the tide is rising) put underneath it the time of the *preceding* L.W. The difference between them is the time occupied in rising, called "duration of rise."

Draw the diagram as shown on the opposite page, a scale of 1 inch to 1 foot has been used here. Make the upright line of any convenient length, and with the half range (2.1 feet), *i.e.*, $2\frac{1}{10}$ inches from scale, draw a semicircle, also a horizontal line where you have placed the point of your compasses. This line indicates the M.T.L. which is 3.1 feet.

The points where the semicircle cuts the upright line will indicate the level of H.W. (5.2 feet) and the level of L.W. (1.0 feet). Measure below the L.W. level another one inch (to represent 1 foot) and thus obtain the chart datum level. Draw the three horizontal lines giving them their proper names.

Work out the angle as shown on the opposite page, and plot this angle on the diagram. As you are using the interval from H.W. it is measured from H.W. The line will intersect the semicircle at the point through which the horizontal line must be drawn to represent the level of the water or "height of the tide" at the time in the question.

On measuring this it will be found to be 4.3 inches, which represents 4.3 feet. By adding this to the depth marked on the chart we obtain the depth of water at the time given in the question.

Worked Example IX.

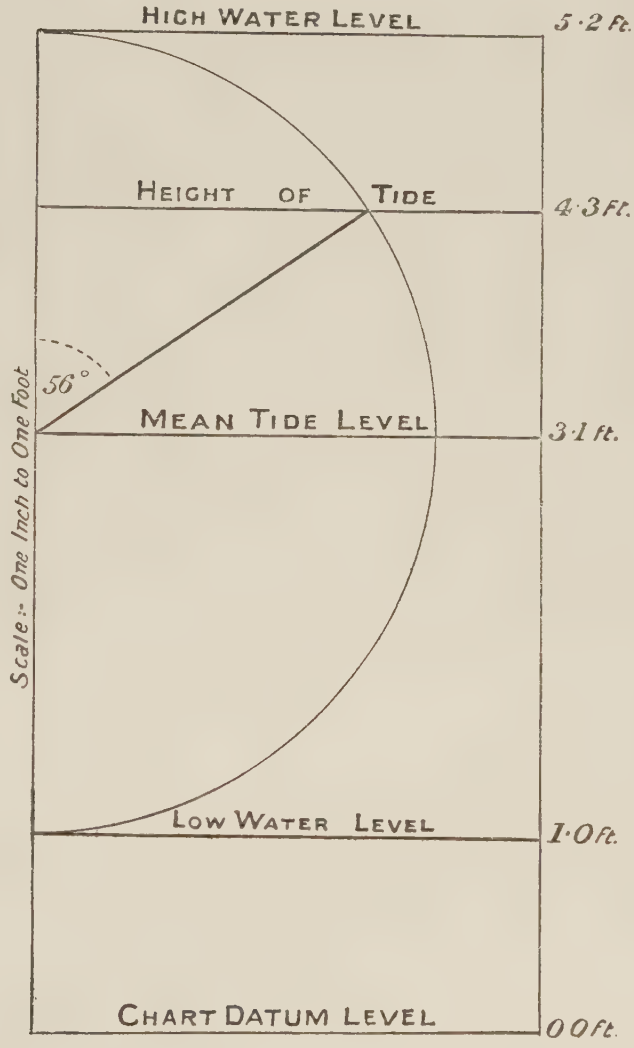
	h.	m.
Time of H.W. at Wellington on 2nd	15	21
Time given in question	13	21
Interval before H. W.	2	0

	feet
Standard.....Height of H.W.	5·2
Standard.....Height of L.W.	1·0
Range of tide	4·2
Half range ..	2·1
Mean tide level	3·1

	h.	m.
Standard time of H.W. Wellington	15	21
Time of preceding L.W. Wellington	8	55
Duration of rise	6	26

h. m. h. m. °
As 6 26 : 2 0 :: 180 : x
or as 386m : 120m :: 180 : x

180
120
3600
180
386)21600(56°
1930
2300
2316



Depth of water below chart datum, as marked on chart	36·0 feet
Height of tide at 13h. 21m. Standard time	4·3 feet
Depth of water at 13h. 21m. Standard time	40·3 feet

Worked Example X.

Standard Port. (Mean time at ship given.)

1925.—On February 3rd, at 03h. 28m. mean time at ship off Singapore, required the correction to be applied to the depth obtained by the leadline before comparing your sounding with the depth marked on the chart.

Instructions for working.—Turn the mean time at ship given in the question into Standard time so that it may be compared with the Standard time given in the Tide Tables. The difference (in time) between the longitude of Singapore and the longitude of the Standard time is 4m. 40s. (call it 5 min.). This is the correction for longitude which must be added to the mean time at ship off Singapore because Singapore is to the Westward of the longitude for which Standard time is given. This gives us 03h. 33m. as the Standard time when the sounding was taken.

Take out (from the Tide Tables) and copy down the time of H.W. or L.W. which is nearest to the time of sounding. In this case it is the H.W. at 05h. 33m. Standard time. The sounding being taken at 03h. 33m. Standard time we get 2h. 0m. as the interval before H.W., and we know that the tide is rising.

Copy down the height of the H.W. corresponding to the time previously chosen, and as the tide is rising, write down underneath it the height of the *preceding* L.W. The difference between these two heights is the "range of the tide." Divide this by two to get the "half range." Subtract the half range from the height of the H.W. to get the mean tide level.

Now copy down the time of H.W. again, write down underneath it the time of the *preceding* L.W., and find the difference between them which is the "duration of rise."

Draw the diagram as on the opposite page, the scale used is $\frac{1}{2}$ inch to 1 foot. Make the upright line of any convenient length, and with the half range (1.7 feet) that is .85 inches from the scale draw a semicircle, also a horizontal line where you have placed the point of your compasses. This line indicates the M.T.L. which is 6.4 feet.

The points where the semicircle cuts the upright line will indicate the level of H.W. (8.1 feet) and the level of L.W. (4.7 feet). Measure below the L.W. level another 2.35 inches to represent 4.7 feet and thus obtain the chart datum level. Draw the three horizontal lines giving them their proper names.

Work out the angle as shown on the opposite page and lay off this angle on the diagram. As you are using the interval from H.W. it is measured from H.W., this line will interesect the semicircle at the point through which the horizontal line must be drawn to represent the level of the water or "height of the tide" at the time of taking the sounding.

This will be found by measurement to be 3.68 inches which represents 7.36 feet and is the correction to be subtracted from the depth obtained by the leadline before comparing it with the depth marked on the chart.

(It would be more simple to use a scale of 1 inch to the foot, but it would make the diagram rather large.)

Worked Example X.

	°	′	
Singapore is in long.	103	50	E
Standard time is for long	105	0	E.
Difference of longitude	1	10	
		4	
Correction for longitude	4m.	40s.	

	h.	m.	
H.W. Singapore	05	33	Standard time
Time of sounding	03	33	Standard time
Inter. before H.W.	2	0	

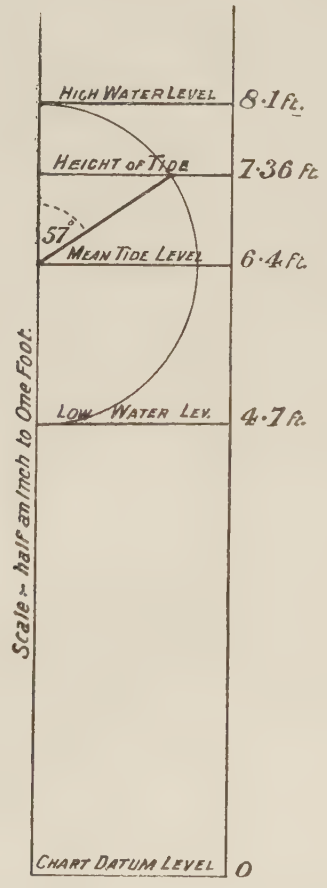
	h.	m.	
Time of soundings	03	28	M.T. ship
Corr. for long. W. +		5	
Time of soundings	03	33	Standard time

	feet.
Height of H.W.	8·1
Height of L.W.	4·7
Range of tide	3·4
Half range	1·7
Mean tide level	6·4

	h.	m.		
Preceding L.W. ..	23	15	on 2nd	
H.W. ..	05	33	on 3rd	
Duration of rise ..	6	18		

h.	m.		h.	m.		°	
As 6	18	:	2	0	::	180	: x
or as 378m		:	120m		::	180	: x

$$
\begin{array}{r}
180 \\
120 \\
\hline
378)21600(57^\circ \\
1890 \\
\hline
2700 \\
2646 \\
\hline
\end{array}
$$



Correction from diagram 3·68 inches which represents 7·36 feet to subtract from the depth obtained by the leadline.

Worked Example XI.

Standard Port. (Mean time at Greenwich given.)

1925.—September 3rd, off Boston, U.S.A., when a chronometer which was correct for M.T.G. indicated 4d. 1h. 45m. 0s., find the depth of water at a position on the chart where the depth marked is 6 fathoms.

Instructions for working.—Look in the "List of Standard Ports" for Boston, turn to the number of the page given, take out and write down the longitude of the Standard time used at Boston. This you will see is for the meridian of 75° W. The difference of longitude between this and the meridian of Greenwich is turned into time and applied to the M.T.G. given in the question to turn it into Standard time.

Copy down the time of H.W. or L.W. which is nearest to this Standard time, write down the Standard time underneath it and find the difference between them. The result is the interval from H.W. or from L.W. as the case may be. The Standard time of the question comes midway between the times of H.W. and L.W. The time of H.W. has been chosen though exactly the same result would have been obtained by working from L.W.

Now copy down the height of the H.W. corresponding to the time chosen, and underneath it write the height of the preceding L.W. (the tide is rising). It will be noticed that there is an asterisk(*) against it which signifies that the L.W. falls that amount *below* chart datum level. In such a case the height of the H.W. must be *added* to the height of the L.W. to obtain the range of the tide. Divide this by two to obtain the "half range." This subtracted from the height of the H.W. gives us the M.T.L.

Find the "duration of rise." This is the difference between the time of the preceding L.W. and the time of the H.W. which we are using.

Work out by proportion the angle to be laid off from H.W. You will find that it comes to exactly 90°. This indicates that the level of the water at the time given in the question is half way between H.W. and L.W.; that is, it coincides with the M.T.L. In such cases a diagram is really not necessary but one is drawn to illustrate the problem.

The value of the M.T.L. added to the depth given in the question will give us the depth required.

Worked Example XI.

	°
Long of Standard time	75 W.
Long. of Greenwich ..	0
Difference of longitude	75° = 5 hours

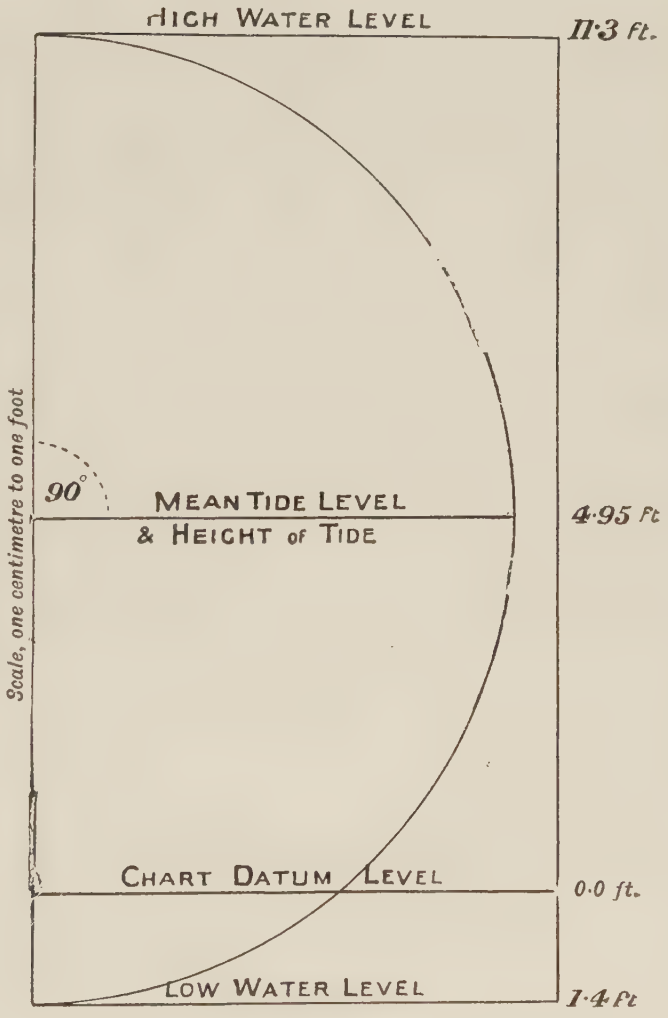
	d.	h.	m.	s.
M.T.G. given in question	4	1	45	0
Correction for longitude W.	—	5	0	0
Standard time of question	3	20	45	0

	h.	m.
Standard time of H.W. Boston	23	50
Standard time of question	20	45
Interval before H.W. ..	3	5

	feet
Height of H.W. Boston ..	11·3
Height of preceding L.W. ..	1·4*
Range of tide	12·7
Half range	6·35
Mean tide level	4·95

	h.	m.
Time of H.W. Boston ..	23	50
Time of preceding L.W. ..	17	40
Duration of rise	6	10

h. m. h. m. °
As 6 10 : 3 5 :: 180 : x
x (the angle) = = 90°



	fms.	ft.
Depth marked on the chart	6	0
Height of the tide	0	4·95
Depth of water at the time in question ..	6	4·95

Worked Example XII.

(Standard Port. Time required to be found.)

A vessel is off St. John, N.B., at 4h. a.m. Standard time on 3rd June, 1925. Find how long she will have to wait before there is 32 feet of water over a 2-fathom shoal.

Instructions.—Find out how much water we must have above chart datum level to give us the required depth of 32 feet.

Turning up to St. John in the Tide Tables we see that at 4h. a.m. the tide is rising. Copy down the time of the L.W. which is next preceding the time given in the question, also the time of the H.W. next following it. The difference between these two times is the "duration of rise."

Then copy down the heights corresponding to these times of L.W. and H.W. The difference between them is the range of the tide. Divide this by two to get the "half range." The half range added to the height of L.W. or subtracted from the height of H.W. gives the M.T.L.

Draw the diagram as on the opposite page. Be very careful with its construction as the accuracy of the angle which you will have to take off is dependent upon it.

The semicircle is drawn with the half range as radius in the usual way.

Having found at the beginning of the work that to have the required amount of water the tide must rise 20 feet above chart datum level, draw a horizontal line at this height.

From the centre used for describing the semicircle draw a line through the point where the 20 feet level intersects the semicircle. This forms an angle with the vertical line at the M.T.L. Measure this carefully with your protractor when you will find that it is 50° from H.W.* 180° is to this angle as the duration of rise is to the interval from H.W. or to the interval from L.W. if the angle from L.W. (130°) is used.

Having worked out the value of this interval by proportion, it must be subtracted from the time of H.W. if the angle from H.W. is used (as shown in the working) or added to the time of the preceding L.W. if the angle of 130° from L.W. is used. The result is the time at which there is the required depth of water.

The difference between this time which you have worked out and the time given in the question is the interval of time during which the vessel will have to wait before there is 32 feet of water.

---

* The value of the angle may also be found from the triangle in the diagram by R.A. plane trigonometry.

$$\text{The formula is cosine angle} = \frac{\text{height of tide above M.T.L. (6·25 ft.)}}{\text{half range (9·65 ft.)}} = 49^\circ\ 38'$$

Worked Example XII.

		feet
Depth of water marked on chart	..	12·0
Depth of water required	..	32·0
Depth required above chart datum level		20·0

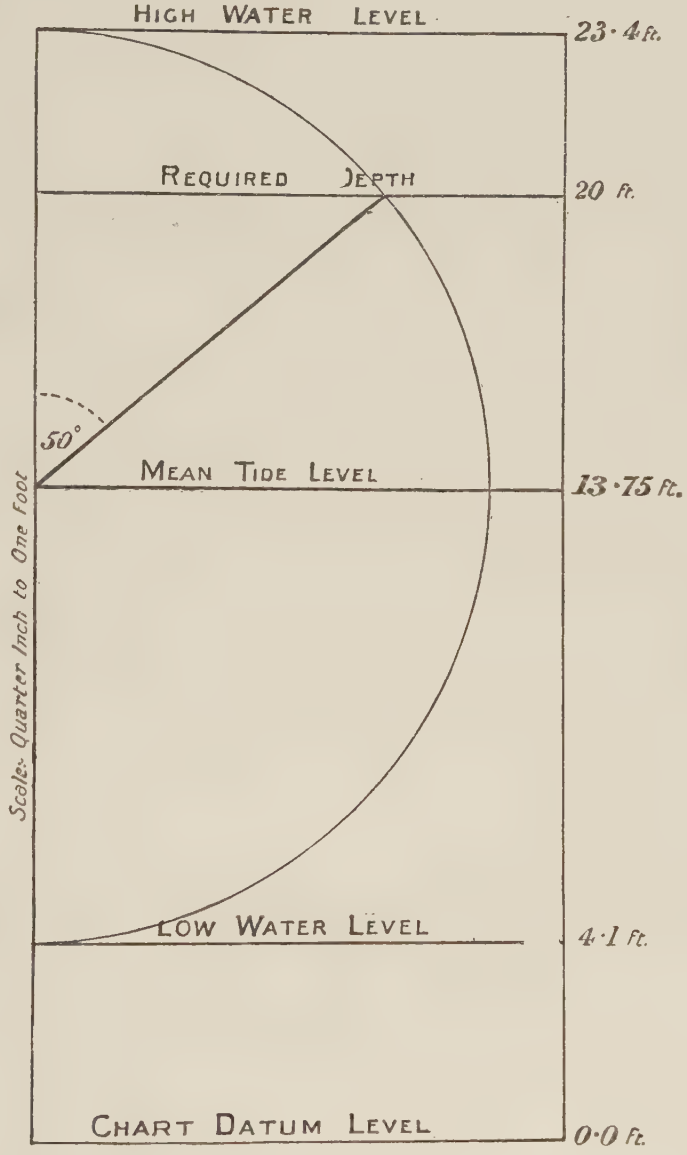
		h. m.
Time of L.W. St. John	..	02 28
Time of H.W. St. John	..	8 42
Duration of rise	.. ..	6 14

		feet
Height of L.W. St. John		4·1
Height of H.W. St. John		23·4
Range of tide	.. ..	19·3
Half range	.. ..	9·65
Mean tide level	.. ..	13·75

	°	′	h. m.
As	180	50	6 14 : x
or as	180	50	374m : x

374
50
m. h. m.
180)18700(104=1 44
180
700
720

		h. m.
Time of H.W. St. John		8 42
Interval from H.W.	..	1 44
Time of required depth	..	6 58
Time in question	.. ..	4 0
Time ship has to wait	..	2 58



Worked Example XIII.

(Local mean time to be found.)

Leaving St. John, N.B., about 1h. a.m. on 8th July, 1925, in a vessel drawing 30 feet of water, find up to what Local mean time it will be possible to pass over a 2-fathom bank with a clearance of 4 feet.

Instructions.—Find out how much water you must have above chart datum level to give a clearance of 4 feet.

Turn up to St. John in the Tide Tables, and, as the question infers (and the time shows) that you are working on a falling tide, copy down the time of H.W. next preceding the time in the question. Underneath it write down the time of the following L.W. The difference between them is the "duration of fall."

Now copy down the heights of the H.W. and the L.W. corresponding to these times, and from them find the range of the tide, half range, and mean tide level.

Construct the diagram very carefully with this data, describing the semicircle with the half range (13.75 feet, 2.29 inches from scale) as radius in the usual way. The scale used for the diagram on the opposite page is $\frac{1}{6}$ inch to the foot.

As we require 22 feet of water above chart datum level ($3\frac{2}{3}$ inches from the scale), draw a horizontal line at this height.

From the centre used for describing the semicircle draw a line through the point where the 22 feet line intersects the semicircle. This line forms an angle with the vertical line at the M.T.L. Measure this with your protractor and you will find that it is 56° from H.W.

Work out by proportion the interval of time which the water will take to fall from H.W. to the 22 feet level.

Add this interval of time to the Standard time of H.W. The result will give you the Standard time when the water will be at the 22 feet level, that is, the Standard time when there will be 34 feet of water.

As the question asks for Local mean time, we must find the "correction for longitude" and apply it to the Standard time. St. John being to the Westward of the meridian of the Standard time, this correction must be subtracted. The remainder is the latest Local mean time at which it will be possible to pass over the bank with a 4 feet clearance.

Worked Example XIII.

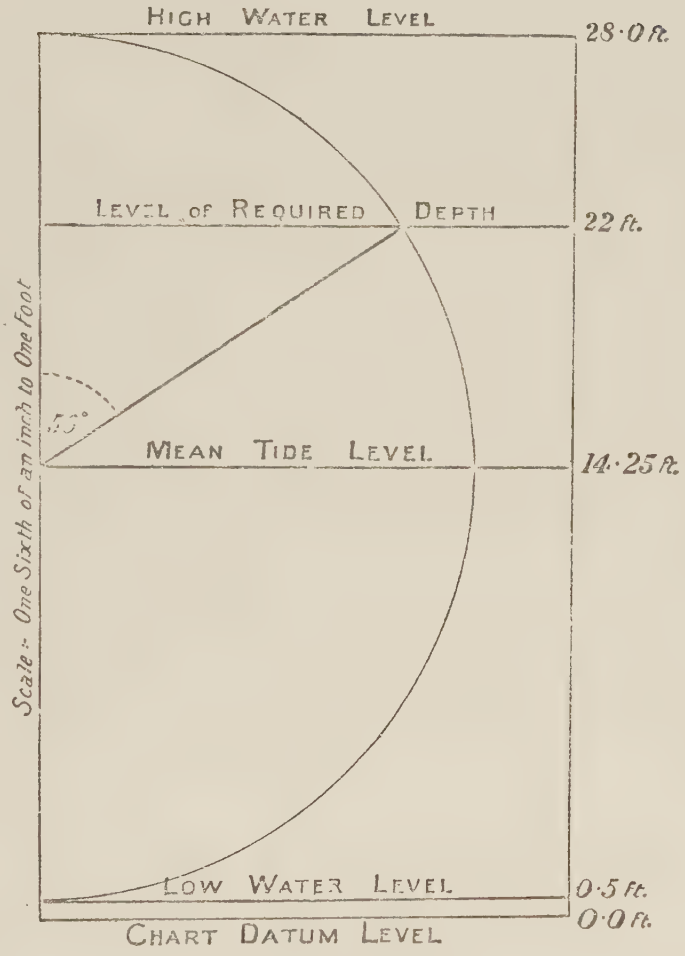
	feet.
Depth of water required to give 4 feet clearance	34
Depth on chart at chart datum level	12
Depth of water required above chart datum level	22

	h. m.
Time of preceding H.W. ..	00 41
Time of following L.W. ..	07 10
Duration of fall	6 29

	feet
Height of preceding H.W.	28·0
Height of following L.W.	0·5
Range of tide	27·5
Half range	13·75
Mean tide level	14·25

	°	°	h. m.	
As	180	: 56	: : 6 29	: x
or as	180	: 56	: : 389m.	: x

389
56
2334
1945
m. h. m.
180)21784(121=2 1
180
378
360
184
180



	°	′	
Long. of St. John ..	66	4	W.
Long. Standard time	60	0	W.
	6	4	
		4	
Corr. for longitude	24m.	16s.	

	h.	m.	
H.W. St. John	00	41	Standard time
Interval after H.W. ..	2	1	
Possible to pass up to	2	42	Standard time
Corr. for longitude W.	—	24	
Possible to pass up to	2	18	Local mean time

EXAMPLES FOR EXERCISE.

Standard Port (Standard Time given).

(These are the same kind of problems as Worked Example I.)

No. 1.—1925.—**February 9th, at 17h. 19m. Standard time off Invergordon, find the correction to apply to the depth obtained by the leadline before comparing it with the depth marked on the chart.**

Ans.—Interval before L.W. 1h. 30m., duration of fall 6h. 7m., Mean tide level 7·9 feet, half range 5·3 feet, angle 44°, gauge correction 3·8 feet to subtract, correction to subtract from leadline 4·1 feet.

No. 2.—**September 17th, 1925, at 03h. 38m. Standard time off Liverpool, a ship drawing 28 feet was in a position where the chart showed 40 feet. Find how much water she had under her keel.**

Ans.—Interval before H.W. 2h. 16m., duration of rise 5h. 35m., Mean tide level 15·1 feet, half range 11·8 feet, angle 73°, gauge correction 3·4 feet to add, height of tide 18·5 feet, depth of water 58·5 feet, depth under keel 30·5 feet.

No. 3.—1925.—**July 11th, at 22h. 20m. Standard time, find the height of the tide and the depth of water off Kingstown in a position where the depth marked on the chart is 6 fathoms.**

Ans.—Interval after L.W. 1h. 12m., duration of rise 6h. 54m., mean tide level 6·7 feet, half range 4·7 feet, angle 31°, gauge correction 4·0 feet to subtract, height of tide 2·7 feet, depth of water 38·7 feet.

Standard Port (Local Mean Time given).

(These are the same kind of problem as Worked Example II.)

No. 4.—1925.—**October 15th, required the height of the tide and the depth of water at 12h. 00m. noon Mean time at ship off Brest in a position where the chart indicates 15 fathoms.**

Ans.—Correction for longitude 18 mins. to add, interval before H.W. 2h. 28m., duration of rise 6h. 1m., Mean tide level 14·75 feet, half range 7·55 feet, angle 74°, gauge correction 2·1 feet to add to Mean tide level, height of tide 16·85 feet, depth of water 17 fathoms 4·85 feet.

No. 5.—1925.—**November 3rd, at 06h. 56m. Local Mean time off Flushing, in a ship drawing 24 feet, required the clearance she will have when passing over a shoal patch on which the chart indicates 30 feet.**

Ans.—Correction for longitude 5 mins. to add, interval before L.W. 2h. 2m., duration of fall 6h. 27m., Mean tide level 6·4 feet, half range 7·0 feet, angle 57°, gauge correction 3·8 feet to subtract, height of tide 2·6 feet, depth of water 32·6 feet. Clearance 8·6 feet.

SECONDARY PORT (Standard Time given).

(These are the same kind of problems as Worked Example III.)

No. 6.—1925.—**January 12th, at 02h. 44m. Standard time, find the height of the tide and the depth of water off Cromarty. Depth marked on chart 20 feet.**

Ans.—Interval after H.W. 1h. 40m., duration of fall 5h. 41m., Mean tide level 8·7 feet, half range 4·2 feet, angle 53°, gauge correction 2·5 feet to add, height of tide 11·2 feet, depth of water 31·2 feet.

No. 7.—1925.—**November 18th, at 14h. 24m. Standard time, a vessel was at anchor off Roscoff. Her draught was 22 feet and the depth marked on the chart was 5 fathoms. What was the depth of water under her keel?**

Ans.—Interval after L.W. 2h. 6m., duration of rise 6h. 2m., Mean tide level 15·75 feet, half range 12·75 feet, angle 63°, gauge correction 5·8 feet to subtract, height of tide 9·95 feet, depth of water 39·95 feet, depth under keel 17·95 feet.

SECONDARY PORTS (Local Mean Time given).

Differences to be Corrected.

(These are the same kind of problems as Worked Example IV.)

No. 8.—1925.—**June 4th, at 04h. 08m. Local Mean time off Soldier's Point, Dundalk, find the correction to apply to the depth obtained by the leadline before comparing it with the depth marked on the chart.**

Ans.—Days from spring tide 3½, corrected time diff. for both high and low water + 0h. 6m., corrected H.W height diff. + 2·3 feet, corrected L.W. height, diff. + 0·9 feet, correction. for longitude 25m. to add to local mean time interval after L.W. 1h. 39m., duration of rise 6h. 35m., Mean tide level 8·1 feet, half range 4·8 feet, angle 45°, gauge correction 3·4 feet to subtract, correction to subtract from leadline 4·7 feet.

No. 9.—**On March 16th, 1925, at 17h. 34m. Mean time at ship being off Wick, where the chart showed 4 fathoms, a vessel had 10 feet of water under her keel. What was her draught?**

Ans.—Days from spring tide 4, corrected time diff. for both high and low water — 0h. 58m., corrected H.W. height diff. — 3·0 feet, corrected L.W. height diff. — 1·6 feet, correction for longitude 12 mins. to add to local mean time, interval after H.W. 2h. 25m., duration of fall 5h. 45m., Mean tide level 5·75 feet, half range 3·55 feet, angle 76°, gauge correction 0·9 feet to add, depth of water 30·65 feet, draught of vessel 20·65 feet, or 20 feet 8 inches.

SECONDARY PORT (Local Mean Time given).

Neap Tide. Low Water.

(This is the same kind of problem as Worked Example V.)

No. 10.—**Find what water a ship drawing 30 feet will have under her keel when anchored off The Nore on May 17th, 1925, at 01h. 40m. Mean time at ship. Depth marked on chart 8 fathoms.**

Ans.—Days from spring tide 7½, which is a neap tide. Time difference — 0h. 10m., H.W. neap difference — 0·5 feet, L.W. neap difference 0·0 feet (nothing), correction for longitude 3 mins. to subtract from mean time at ship, interval from L.W. 0h. 0m. (time in question is at L.W.), height of L.W. 2·4 feet, depth of water 50·4 feet, water under keel 20·4 feet.

SECONDARY PORTS (Standard Time given).

Spring Tides. Below Datum.

(These are the same kind of problem as Worked Example VI.)

No. 11.—1925.—**May 10th, at 07h. 35m. Standard time off Ramsgate, find the height of the tide and the depth of water in a position where the chart indicates 16 feet.**

Ans.—Spring differences used. Interval before low water 0h. 23m., duration of fall 7h. 37m., Mean tide level 8·25 feet, half range 8·55 feet, angle 9°, gauge correction 8·45 feet, height of tide 0·2 feet below datum, depth of water 15·8 feet.

No. 12.—**Find the height of the tide and the depth of water off Grangemouth at 21h. 27m. Standard time on May 9th, 1925. Depth marked on the chart 4 fathoms.**

Ans.—One day from spring tide. The difference between spring and neap differences being small, spring differences are used throughout. Interval after L.W. 0h. 44m., duration of rise 7h. 19m., Mean tide level 7·6 feet, half range 9·6 feet, angle 18°, gauge correction 9·1 feet, height of tide 1·5 feet below datum, depth of water 22·5 feet.

STANDARD PORT (To Find the Time).

(This is the same kind of problem as Worked Example VII.)

No. 13.—1925.—**January 6th, off Leith, find the Standard time during the forenoon watch when the height of the tide will be 2 fathoms above chart datum level.**

Ans.—Duration of rise 6h. 12m., Mean tide level 10·3 feet, half range 4·9 feet, angle 70°, interval before high water 2h. 25m., the tide will be 2 fathoms above chart datum level at 10h. 04m. Standard time.

SECONDARY PORT (To Find the Time).

(Worked Example VIII. is the best guide for this problem.)

No. 14.—1925.—**Off Dunbar. Find the Mean time at ship during the afternoon watch on February 13th at which there will be 30 feet of water on a patch where the chart indicates 4 fathoms.**

Ans.—Days from spring tide 3, corrected time diff. for both high and low water — 0h. 17m., corrected H.W. height diff. — 1·2 feet, corrected L.W. height diff. + 0·3 feet, duration of rise 6h. 44m., Mean tide level 9·35 feet, half range 6·45 feet, angle 59°, interval after low water 2h. 12m., there will be 30 feet of water at 12h. 55m. Standard time or 12h. 45m. Mean time at ship. Correction for longitude 10 mins. to subtract from Standard time.

MISCELLANEOUS EXAMPLES.

No. 15.—**Being off Zeebrugge on September 16th, 1925, at 11h. 55m. Local Mean time, a cast of the lead was taken. Required the correction to be applied to the depth obtained by the leadline before comparing it with the depth marked on the chart.**

Ans.—Days from spring tide 4½, corrected H.W. time diff. — 0h. 36m., corrected H.W. height diff. + 1·1 feet, correction for longitude 7 mins. to add to local mean time, interval from H.W. nil (cast was taken at high water), height of tide 13·1 feet, which is also the correction to subtract from the leadline.

No. 16.—1925.—**May 12th, find the depth of water at Pwllheli at 16h. 29m. Local Mean time. Depth marked on chart 16 feet.**

Ans.—Days from spring tide 2½, corrected H.W. time diff. — 2h. 15m. (also used for L.W.), corrected L.W. height diff. — 0·4 feet, correction for longitude 18 mins. to add to local mean time, interval from L.W. nil (depth is required at low water), height of tide 0·6 feet, depth of water 16·6 feet.

No. 17.—1925.—**June 10th, find the depth of water on Port Madoc bar at 19h. 09m. Local Mean time, the depth indicated by the chart being 6 feet.**

Ans.—Days from spring tide 2½, H.W. spring diff. used for times of both high and low water, correct H.W. height diff. — 1·7 feet, corrected L.W. height diff. — 0·2 feet, Mean tide level 7·2 feet, duration of rise 6h. 12m., interval after L.W. or before H.W. 3h. 6m. As the tide takes 6h. 12m. to rise, and the depth is required at 3h. 6m. after low water, the tide must be at half-flood, its height is, therefore, at mean tide level. The depth of water is consequently the depth shown on the chart + the mean tide level. This makes it 13·2 feet.

No. 18.—1925.—**October 15th, a vessel drawing 15 feet was anchored in Morecambe Bay. Find what water she would have under her keel when entering Barrow Docks at 08h. 49m. Mean time at ship. Depth on chart 8 feet.**

Ans.—Days from spring tide 3½, corrected H.W. time diff. — 0h. 7m., corrected L.W. time diff. + 0h. 10m., corrected H.W. height diff. 0·0 feet, corrected L.W. height diff. + 0·1 feet, Mean tide level 15·4 feet, correction for longitude 13 mins. to add to mean time at ship, duration of rise 5h. 24m., interval before H.W. 0h. 34m., half range 10·6 feet, angle 19°, gauge correction 10·0 feet to add to mean tide level, depth of water 33·4 feet, depth under keel 18·4 feet.

No. 19.—1925.—**On the afternoon of September 4th off Zierikzee, find the Mean time at ship when the height of the tide will be 9 feet above chart datum level.**

Ans.—Spring tide, spring diffs. used throughout, duration of rise 6h. 51m., Mean tide level 5·3 feet, half range 5·4 feet, angle 47°, interval before H.W. 1h. 47m., the height of the tide will be 9 feet above chart datum level at 13h. 55m. Mean time at ship. Correction for longitude 4 minutes to subtract from Standard time.

No. 20.—**On October 2nd, 1925, at 01h. 15m. Local mean time, being off Wellington, New Zealand, required the depth of water in a position where the chart indicates 35 feet.**

Ans.—Correction for longitude 9m. to subtract from L.M.T., interval before H.W. 2h. 22m., duration of rise 6h. 14m., mean tide level 3.0 feet, half range 1.8 feet, angle 68° from H.W., gauge correction 0.7 feet to add to mean tide level, correction to add to depth marked on the chart 3.7 feet, depth of water 38.7 feet.

No. 21.—1925.—**Off Wellington, New Zealand, on September 2nd at 13h. 21m. Standard time, a sounding was taken. Required the correction to be applied to the depth obtained by the leadline before comparing it with the depth marked on the chart.**

Ans.—Interval before H.W. 2h. 0m., duration of rise 6h. 26m., mean tide level 3.1 feet, half range 2.1 feet, angle from H.W. 56°, gauge correction 1.2 feet above mean tide level, correction to subtract from the depth obtained by leadline 4.3 feet.

No. 22.—**November 3rd, 1925. What correction must be applied to the depth obtained by a cast of the lead in Wellington harbour, New Zealand, before comparing it with the depth marked on the chart. At the time of taking the cast a chronometer indicated 2d. 19h. 17m. 0s. which was correct Mean time at Greenwich.**

Ans.—Correction for longitude 11h. 30m. to add to the given Mean time at Greenwich, interval after H.W. 0h. 39m., duration of fall 6h. 14m., mean tide level 3.05 feet, half range 1.85 feet, angle from H.W. 19°, gauge correction 1.75 feet to add to mean tide level, correction to subtract from depth obtained by leadline 4.8 feet.

No. 23.—**Being off Singapore at 12h. 04m. Standard time on January 1st, 1925, a cast of the lead was taken and a depth of 9 fathoms was obtained. How much must this be reduced before comparing it with the depth marked on the chart?**

Ans.—Interval before H.W. 2h. 34m., duration of rise 5h. 59m., mean tide level 6.6 feet, half range 2.3 feet, angle from H.W. 77°, gauge correction 0.5 feet above mean tide level, depth must be reduced 7.1 feet before comparing with chart.

No. 24.—1925.—**March 5th A.M. at ship, when a chronometer showing correct Mean time at Greenwich indicated 5d. 4h. 9m. 0s., it was required to know the depth of water at a position where the chart of Singapore Harbour gave 6 fathoms 3 feet.**

Ans.—Correction for longitude 7h. 0m. to add to the given Mean time at Greenwich, interval after H.W. 5h. 41m., interval before L.W. 1h. 59m., duration of fall 7h. 40m., mean tide level 4.95 feet, half range 2.25 feet, angle from H.W. 133.5°, angle from L.W. 46.5°, gauge correction 1.55 feet below mean tide level, correction to add to the depth marked on the chart 3.4 feet, depth of water 42.4 feet.

No. 25.—**On July 6th, 1925, at 16h. 24m. Mean time at Greenwich, required the correction to be applied to the leadline depth obtained off St. John, N.B., before comparing it with the depth marked on the chart.**

Ans.—Correction for longitude 4h. 0m. to subtract from the given Mean time at Greenwich, interval after H.W. 0h. 53m., duration of fall 6h. 14m., mean tide level 13.95 feet, half range 11.95 feet, angle from H.W. 25.5°, gauge correction 10.85 feet to add to mean tide level, correction 24.8 feet to subtract from leadline depth before comparing with chart.

No. 26.—**Off Boston, U.S.A., on the afternoon of September 2nd, 1925, at what Standard time will there be sufficient water for a vessel drawing 30 feet to pass over a bank having 4 fathoms 3 feet of water over it at chart datum level so that she may have a clearance of 5 feet below the keel?**

Ans.—Duration of rise 6h. 10m., mean tide level 5.1 feet, half range 6.2 feet, 35 feet of water required which is 8 feet more than marked on the chart, angle from H.W. 62°, required depth of water at 20h. 54m. Standard time.

No. 27.—**Up to what Standard time will it be safe to leave St. John, N.B., on the morning of July 2nd 1925, to pass over a 4 fathom bank with a margin of 6 feet if the draft of the ship is 36 feet?**

Ans.—Duration of fall 6h. 7m., mean tide level 13.5 feet, half range 9.5 feet, 42 feet of water required which is 18 feet more than marked on the chart, angle from H.W. 62°, 2h. 6m. after H.W., safe up to 10h. 10m. Standard time.

No. 28.—**How long will a ship have to wait from 05h. 00m. Standard time on 5th June, 1925, off St. John, N.B., to pass over a 2½ fathom shoal if she is drawing 28 ft. 6 ins. and desires an 8 feet clearance?**

Ans.—Duration of rise 6h. 12m., mean tide level 13.6 feet, half range 11.3 feet, 36.5 feet of water required which is 21.5 feet more than marked on the chart, angle from H.W. 46°, required depth at 08h. 43m. Standard time, interval during which the ship has to wait 3h. 43m.

No. 29.—**Up to what Standard time will it be safe to cross a bank showing 5 fathoms off Boston, U.S.A., in a 28 ft. draft vessel so as to have a clearance of 6 feet below the keel on November 1st, 1925, about noon?**

Ans.—Duration of fall 6h. 20m., mean tide level 4.7 feet, half range 6 feet, 34 feet of water required which is 4 feet more than is marked on the chart, angle from H.W. 97°, 3h. 25m. after H.W., safe up to 14h. 58m. Standard time.

No. 30.—**Off St. John, N.B., on the evening of 3rd July, 1925, at what Local Mean time will there be a depth of 35 feet of water over a bank with 2 fathoms 2 feet marked on the chart?**

Ans.—Duration of rise 6h. 12m., mean tide level 14.5 feet, half range 11.3 feet, required depth 35 feet, which is 21 feet more than is marked on the chart, angle from H.W. 55°, required depth at 19h. 23m. Standard time, correction for longitude 24 minutes to subtract, which gives 18h. 59m. Local Mean time.

No. 31.—**Up to what Local Mean time will it be possible to cross over a shoal patch of $3\frac{1}{2}$ fathoms with a 5 foot clearance in a vessel having a draft of 23 feet 6 inches on the afternoon of October 4th, 1925, the vessel being off Boston, U.S.A.**

Ans.—Duration of fall 6h. 19m., mean tide level 4.7 feet, half range 6.0 feet, required depth 28 ft. 6 ins. which is 7.5 feet more than is marked on the chart, angle from H.W. 62°, 2h. 11m. after H.W., safe up to 14h. 53m. Standard time, correction for longitude 16 minutes to add to Standard time, giving 15h. 9m. as the Local Mean time up to which it is possible to cross the shoal.

PART II.

Containing the work required for Masters.

Latitude by the Pole star.
Latitude by meridian altitude of the moon.
Curve of deviations on Napier's diagram.
Great circle sailing.
Composite sailing.
Problems worked with the planets.
Essays.
Deviation questions and the deviascope.
Coal consumption.

In addition to the above, masters are required to work any of the problems prescribed for second and first mates that may be given to them, also the chart and meteorology papers.

They will be examined orally on the use of the sextant, barometer, and other instruments with which they should be acquainted, and particularly on their **general** knowledge of subjects connected with their profession.

They are also expected to read up the following books in addition to the Barometer manual and the Seamen's handbook on meteorology :—

Briggs' elementary science.
The principal winds and currents of the globe.
Ocean passages.
The Admiralty tide tables.

Latitude by Altitude of the Pole Star.

Candidates are required to work this problem by means of the " Pole star tables " given in the *Nautical Almanac* on pages 158 to 161.

The Pole star tables are also given at the end of this book

If the Pole star was situated exactly at the North Pole of the heavens, its true altitude at any time would be equal to the latitude, and these tables of corrections would not be required.

Order of Working.

Find the R.A.M., which in this problem is called the Local Sidereal time of observation.

Correct the observed altitude to find the true altitude.

Find the First Correction.—This is given in Table I. of the Pole star tables for every two minutes of local sidereal time. With the number of hours at the top of the column and the nearest given number of minutes in the left-hand margin, take out the correction and apply it to the altitude according to its sign, plus or minus.

When your local sidereal time is in between two of the given times, a mental interpolation will give greater accuracy than is obtained by simply copying down the correction for the nearest given one.

Find the Second Correction.—This is given in Table II. for each five degrees of altitude and twenty minutes of local sidereal time. With the nearest 5° of altitude at the top of the column and the nearest twenty minutes of local sidereal time at the side of the page, take out the corresponding correction and apply it to the altitude. It is always additive.

Find the Third Correction.—This is given in Table III. of the Pole star tables for the first day of every month, and for every hour of local sidereal time. With the nearest given date at the top of the column and nearest hour of local sidereal time in left-hand margin, take out the corresponding correction and apply it to the altitude. It must be added or subtracted according to its sign.

It is not necessary to interpolate for these corrections, as the changes are only small ones. Mental interpolation, however, is good, and may result in you getting a mark more than the other man who has not done so.

The true altitude, after these three corrections have been applied to it, becomes the latitude.

The Right Ascension of Polaris is given in the *Nautical Almanac* on page 1 of the month.

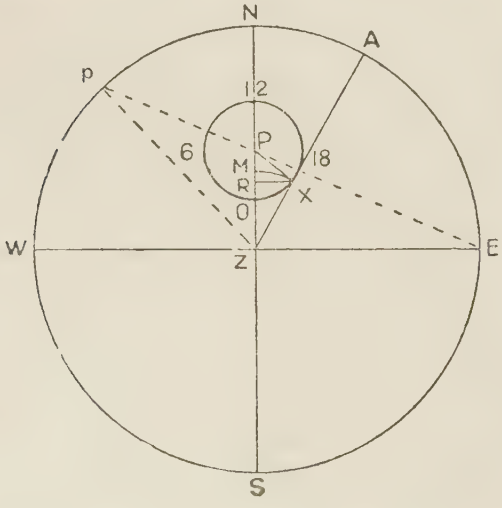
LATITUDE BY POLE STAR.

Figure for Latitude by Pole Star.

R.A.M. or Local Sidereal Time = 22h. 0m.

Observed Altitude of Polaris = 43° ; R.A. of Polaris = 1h. 30 m.

Describe the circle *N E S W* to represent the rational horizon, and put in the observer's meridian *N Z S* and the prime vertical *W Z E*, *Z* being the observer's zenith as before. The approximate position of *P*, the elevated pole, can then be put in by the D.R. latitude, if given, or if it is not given, then by the observed altitude of Polaris. Make angle *N Z p* = D.R. latitude or observed altitude, in this case observed altitude = 43°. ∴ *N Z p* = 43°.



A line from *p* to *E* crosses the meridian at *P*, the approximate position of the pole. Describe a small circle around *P* to represent the path of the star about the pole. The declination of Polaris being 88° 54′ N., it is in reality only 1° 6′ from the pole, but the circle may be much exaggerated, as shown in the figure for the purpose of illustration. This small circle is now a 24-hour circle, and the figures 0, 6, 12, 18 represent westerly hour angle. The hour angle of the star is the difference between the R.A.M. and the star's R.A. When the star's R.A.

is the greater it is East, and when the star's R.A. is the lesser the hour angle is West.

In this case the R.A.M. is 22h. and the star's R.A. = 1h. 30m., the star's hour angle is, therefore, 20h. 30m. W. or 3h. 30m. E. of the observer's meridian. Make angle $Z\ P\ X$ = 3h. 30m. or 52°, and X will be the position of Polaris on the small circle.

Draw in $Z\ X\ A$, join $P\ X$, and make $X\ R$ perpendicular to the meridian.

Now $N\ P$ represents the latitude and $A\ X$ the altitude, and if X were at P then $N\ P$ would be the latitude and the altitude, and there would be no corrections to be applied. What is required to be done is to make $A\ X$ equal to $N\ P$ or the altitude equal to the latitude, and, therefore, the difference between the lengths of $A\ X$ and $N\ P$ is the sum of the corrections to be applied to the altitude.

With centre at Z and radius $Z\ X$ describe arc $X\ M$; then $A\ X = N\ M$, so that $N\ M - N\ P$ = corrections.

Then $P\ R$ is the first correction, which is subtractive, and $M\ R$ is the second correction, which is additive.

The third correction is due to the periodical variations of the right ascension and declination of Polaris, the tables having been computed for a fixed right ascension and declination. It is always small, and cannot be shown in the figure.

It will be seen from the figure that when the star is on the meridian (hour angle 0) the first correction is equal to the star's polar distance, and is subtractive. When the hour angle is 12 hours the star is on the meridian below the pole, the first correction again being equal to the polar distance, but additive.

When the star's hour angle is 6 hours, a line from X perpendicular to the meridian falls on P, and the first correction is 0.

If the hour angle is less than 6 hours, the pole star is nearer to the observer than is the pole. Its observed altitude is, therefore, too large, for which reason the first correction is minus.

When the hour angle is more than 6 hours East or West the star is further away from the observer than is the pole, its altitude is consequently too small, for which reason the first correction is plus.

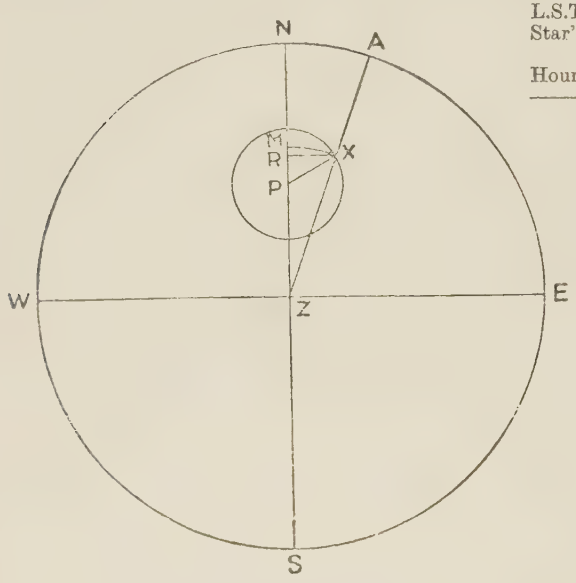
Worked Example I.

On 21st March, 1929, in longitude 17° 30′ W., when a chronometer (corrected) indicated Mean time at Greenwich 06h. 56m. 30s., the observed altitude of the Pole star out of the meridian was 41° 26′, height of the eye 23 feet, index error 2′ 00″ to subtract. Required the latitude.

(The pole star's hour angle must be found before its position can be fixed in the figure.)

Long. W.		d.	h.	h.	m.	s.
17° 30′	R., . .	21	06	=11	53	04·7
4	Corr. 56·5m.,			+		9·3
60) 70° 0′	R. corrected,			11	53	14·0
1h. 10m.						

	d.	h.	m.	s.
G.M.T., . . .	21	06	56	30
Long. W., . . .		1	10	0
S.M.T., ...	21	05	46	30
R., ...		11	53	14
L.S.T., ...		17	39	44
Star's R.A., . . .		01	35	·02
Hour angle, . . .		7	55	18 E.



The circle $N\,E\,S\,W$ represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z represents observer's zenith.
$N\,Z\,S$,, observer's meridian.
$W\,Z\,E$,, prime vertical.
P ,, pole (celestial).

Small circle represents the parallel of declination enlarged for the purpose of illustration.

X represents Polaris (7h. 55m. East of meridian).

$Z\,P\,X$ represents star's hour angle.
$A\,X$,, star's altitude.
$N\,P$,, the latitude.

$N\,P \sim A\,X$ = sum of corrections to be applied to altitude.
$P\,R$ represents the 1st correction.
$R\,M$,, 2nd correction (this is the difference between $Z\,X$ and $Z\,R$).

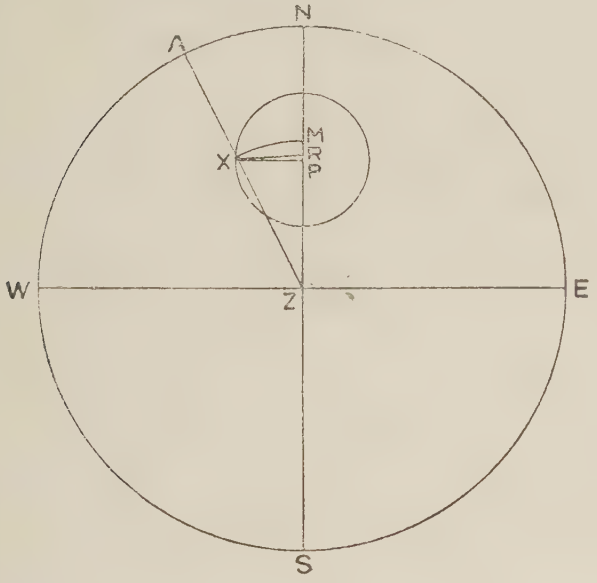
Third correction cannot be illustrated, but it is due to the variations in the R.A. and declination of Polaris.

	°	′
Obs. alt., ...	41	26
Ind. err., ... —		2
	41	24
Dip, ... —		4·7
	41	19·3
Ref., ... —		1·1
True alt., ...	41	18·2
Corr. I., ... +		31·0
Corr. II., ... +		·4
Corr. III., ...		0
Latitude, ...	41	49·6 N.

Worked Example II.

On 23rd December, 1929, at 01h. 32m. Mean time at ship in longitude 148° 54′ W., the observed altitude of Polaris out of the meridian was 39° 14′, height of eye 21 feet. Required the latitude.

(The star's hour angle must be found before its position can be fixed in the figure, see below.)



EXPLANATION OF FIGURE.

The circle *N E S W* represents a stereographic projection of the celestial sphere on the plane of the rational horizon.

Z represents observer's zenith.
N Z S ,, observer's meridian.
W Z E ,, prime vertical.
P ,, pole.

Small circle represents the parallel of declination, enlarged for the purpose of illustration.

X represents Polaris (6h 1m. W. of meridian).
Z P X ,, star's hour angle.
A X ,, star's altitude.
N P ,, the latitude.
N P ~ A X represents sum of corrections to be applied to altitude.

P R represents 1st correction.
* *R M* ,, 2nd correction (difference between *Z X* and *Z R*).

3rd correction is due to the variations in the R.A. and Dec. of Polaris, and thus cannot be shown in the figure.

Long. W.		d.	h.	m.	s.
148° 54′	S.M.T.,	23	01	32	00
4	Long. W., +		9	55	36
595° 36′	G.M.T.,	23	11	27	36
9h. 55m. 36s.					

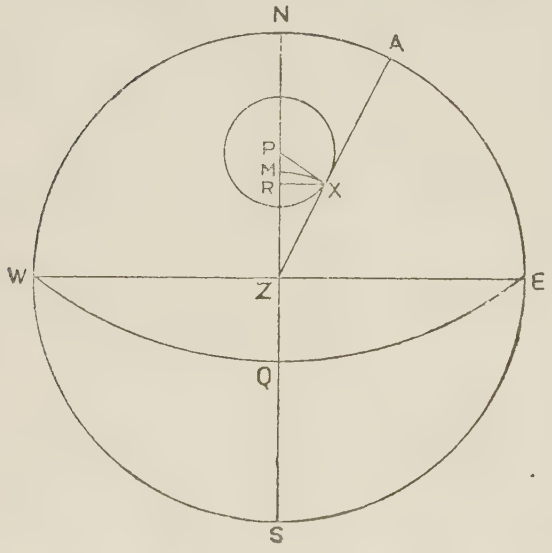
	d.	h.	h.	m.	s.
R.,	23	10	=06	05	50·1
Corr. 1m. 28s.,			+		14·5
R. corrected,			06	06	04·6
S.M.T.,			+01	32	00
L.S.T.,			07	38	05
Star's R.A.,			01	37	00
Hour angle,			6	01	05 W.

	°	′	
Obs. alt.,	39	14	
Dip,	—	4·5	
	39	09·5	
Ref.,	—	1·2	
True alt.,	39	08·3	
1st corr.,	+	0·6	
2nd corr.,	+	0·5	
	39	09·4	
3rd corr.,	—	0·2	
Latitude,	39	09·2	N.

* The *P* and *R* being nearly in the same position on the meridian, the 1st correction is very small. The 2nd correction appears in the figure to be much larger than it really is on account of the very great magnification of the parallel of declination, which is in reality too close to the pole to be drawn in, it must therefore be enlarged.

Worked Example III.

On 4th August, 1929, at 01h. 03m. Apparent time at ship in longitude 152° 30′ E., the observed altitude of *a* Ursæ Minoris (*Polaris*) off the meridian was 36° 46′, index error 1′ 30″ to subtract, height of eye 39 feet. Required the latitude.



The circle *N E S W* represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.

N Z S the observer's meridian.

W Z E the prime vertical.

P the pole.

W Q E the equinoctial.

The small circle represents the parallel of declination enlarged for the purpose of illustration.

X represents the star 3h 41m. East of the meridian, *Z P X* the star's hour angle, *A X* its altitude, *N P* the latitude, *N P ~ A X* = the sum of the corrections to be applied to the altitude, *P R* represents the first correction, *R M* represents the second correction, which is the difference between *Z X* and *Z R*.

The third correction cannot be illustrated, but it is due to the variations in the right ascension and declination of Polaris.

Long. E.		d.	h.	m.	s.
152° 30′	S.A.T., .	4	01	03	00
4	Long. E., . —		10	10	00
6,0)61,0° 0′	G.A.T., .	3	14	53	00
10h. 10m. 0s.					

	d.	h.	h.	m.	s.
E., . .	3	14	=11	53	56·5
Corr. 53m.,			+		·2
E. corrected,			11	53	56·7

	h.	m.	s.
H.A.T.S., .	13	3	0
E., —	11	53	57
S.M.T.,	4 01	09	03
Long. E., —	10	10	0
G.M.T.,	3 14	59	03

	d.	h.	h.	m.	s.
R., ...	3	14	=20	46	38·7
Corr. 59m., . . .			+		9·7
R. corrected, . . .				20 46	48
S.M.T., ...			+01	09	03
L.S.T., . . .				21 55	51
Star's R.A., . . .				01 36	44
Hour angle, . . .				3 40	53 E.

	°	′
Obs. alt., ...	36	46
Ind. err., ... —		1·5
	36	44·5
Dip, ... —		6·1
	36	38·4
Ref., ... —		1·3
True alt., ...	36	37·1
Corr. I., ... —		36·7
	36	00·4
Corr. II., ... +		0·3
	36	00·7
Corr. III., ... —		0·3
Latitude, ...	36	00·4 N.

Examples for Exercise XXI.

(1) On 18th March, 1929, at 03h. 16m. Mean time at ship, in longitude 32° W., the observed altitude of the Pole star (*a* Ursæ Minoris) out of the meridian was 45° 19′, height of eye 35 feet, index error 1′ 30″ to add. Required the latitude.

(2) On 17th April, 1929, at 23h. 39m. Mean time at ship, in longitude 147° 20′ W., the observed altitude of Polaris off the meridian was 34° 58′, index error 1′ 00″ to subtract, height of eye 27 feet. Required the latitude.

(3) On 20th June, 1929, at 04h. 03m. Apparent time at ship, in longitude 165° 18′ E., the observed altitude of *a Ursæ Minoris* (Polaris) out of the meridian was 50° 59′, height of the eye 20 feet. Required the latitude.

(4) On 5th August, 1929, at 22h. 28m. Apparent time at ship, in longitude 30° 40′ W., the observed altitude of the Pole star out of the meridian was 61° 09′, height of eye 30 feet. Required the latitude.

(5) On 23rd December, 1929, in longitude 149° 30′ W., when a chronometer (corrected) indicated Mean time at Greenwich 15h. 17m. 40s., the observed altitude of Polaris out of the meridian was 42° 20′, index error 1′ 30″ to add, height of eye 26 feet. Required the latitude.

(6) On 10th January, 1929, in longitude 20° 10′ E., when a chronometer (corrected) indicated Mean time at Greenwich (9th January) 22h. 53m. 40s., the observed altitude of Polaris out of the meridian was 36° 02′, index error 1′ 00″ to subtract, height of the eye 24 feet. Required the latitude.

LATITUDE BY MERIDIAN ALTITUDE OF THE MOON.

When the sun is on the meridian of the observer we know that the time at ship is apparent noon.

The mean time at which the moon crosses the meridian of Greenwich on each day is given us on page ii. of the month in the *Nautical Almanac*.

The upper and lower passages are given ; the upper one is always to be used.

If the observer is not on the meridian of Greenwich, a correction for longitude must be applied to the time of the meridian passage at Greenwich to find the time of the meridian passage at ship. Note that this correction is not the longitude in time, but a correction due to the revolution of the earth and the changing position of the moon, and that when it is applied to the meridian passage taken from the *Almanac* it gives us the mean time at ship when the moon is on the meridian of the ship.

The moon passes the meridian of Greenwich later each day by the number of minutes in the column headed " Diff.," which is placed alongside the column containing the meridian passage.

In the interval between two such transits the moon passes over 360° of longitude. It, therefore, follows that the mean time of transit over any meridian of **West** longitude is **later** than that over the meridian of Greenwich by $\frac{\text{long. in time}}{24 \text{ hours}} \times$ diff.

It also follows that the mean time of transit over any meridian of **East** longitude is **earlier** than that over the meridian of Greenwich by $\frac{\text{long. in time}}{24 \text{ hours}} \times$ diff.

Having calculated this correction and found the mean time at ship when the moon is on the meridian, the longitude in time applied to it will give us the mean time at Greenwich.

A few worked examples will make this clearer. They are done as follows :—

Take out the time of the upper meridian passage for the given day from page ii. of the month in the *Nautical Almanac*. (Also given at the end of this book.)

Then copy down the number of minutes in the adjoining " diff." column, using the preceding " diff." if longitude is E., but the following " diff." if longitude is W.

Turn the longitude into time, as shown in the margin.

Multiply the number of minutes in the " diff." column by the longitude in time, and divide by 24. The result is the correction for longitude. Add it to the mer. pass. if Long. is W., subtract it from the mer. pass. if longitude is E. This gives you the S.M.T. Apply the longitude in time to get the G.M.T.

Worked Example I.

On 20th January, 1929, in longitude 150° E., find the Mean time at Greenwich when the moon is on the meridian of the ship.

Long. E.		d.	h.	m.	Diff. 55m.
150°	Meridian passage, 20th, .		19	48	10
4	Corr. for long. E., . .	—		22·9	6) 550
6,0) 60,0	S.M.T., ...	20	19	25·1	4) 91·7
10 hrs.	Long. in time E., . .	—	10	00	22·9
	G.M.T., ...	20	09	25·1	

This correction for longitude may be taken out by inspection from the "Table of proportional parts" on page 204 in the *Nautical Almanac*.

Diff. 56 (nearest to 55) at top of column, and 10h. (longitude in time) in right-hand margin gives 23m. as the correction. This agrees with the calculation.

Worked Example II.

On 26th April, 1929, in longitude 100° 50′ W. find the G.M.T. at which the moon will be on the meridian of the ship.

Long. W.		d.	h.	m.	Diff. 48m.
100° 50′	Meridian passage, 26th, .		01	35	6·7
4	Corr. for long. W., . .	+		13·4	336
6,0) 40,3 20	S.M.T., ...	26	01	48·4	288
6h. 43m. 20s.	Long. in time, W., . .	+	6	43·3	6) 321·6
6h. 43·3m.					4) 53·6
6·7 hrs.	G.M.T., ...	26	08	31·7	13·4

Worked Example III.

On 18th June, 1929, in longitude 60° E., find the Mean time at Greenwich when the moon would be on the meridian of the ship.

Long. E.		d.	h.	m.	Diff. 44m.
60°	Meridian passage, 18th, .		21	29	4
4	Corr. for long. E., . .	—		7·3	6) 176
6,0) 24,0	S.M.T., ...	18	21	21·7	4) 29·3
4 hrs.	Long. in time E., . .	—	4	00	7·3
	G.M.T., ...	18	17	21·7	

Examples for Exercise XXII.

In the following examples required the Mean time at Greenwich when the moon will be on the meridian of the ship :—

(1) On 19th January, 1929, in longitude 125° 45′ E.
(2) On 23rd January, 1929, in longitude 136° 40′ W.
(3) On 27th April, 1929, in longitude 45° E.
(4) On 28th April, 1929, in longitude 50° 41′ W.
(5) On 18th June, 1929, in longitude 40° 50′ E.
(6) On 21st June, 1929, in longitude 20° 50′ W.
(7) On 23rd June, 1929, on the meridian of Greenwich.

To Find the Latitude.

The work should be carried out in the following order :—

Find the G.M.T.—This is done in the manner already explained.

Correct the Declination.—The moon's declination for each two hours of every day is given on pages vii to x of the month in the *Nautical Almanac*. Take out the declination for the given number of hours which are next less than your G.M.T., and write it down. For example, if your G.M.T. was 03h. 42m. you would take out the declination for 02h. At the same time, copy down the number which is placed on a level midway between the 02h. and the next following given time, which is 04h. This number is the change (expressed in minutes) in the declination between 02h. and 04h. Divide this by 2, the result being the number of minutes which the declination has changed in 1 hour, generally called the " variation in 1 hour."

Multiply the variation in 1 hour by the odd hour and decimal parts of an hour in the G.M.T., which will give you the correction to apply to the declination which you have already copied down. This correction must be added if the declination is increasing, but subtracted if it is decreasing. The result is the corrected declination.

Example.

G.M.T., June, 18d. 03h. 42m.

d. h.	°	′	
Decl. for 18 02, .	14	26·9	S.
Corr. for 1·7h., . .	+	20·2	
Corrected decl., . .	14	47·1	S.

Change in 2 hrs., . .	23·8
Change in 1 hr., . . .	11·9
(Var. in 1 hr.),	1·7
	833
	119
	20·23

The correction of the declination for the odd 1h. 42m. may be checked by the " Table of proportional parts " on pages 204 to 208 of the *Nautical Almanac*.

With the change in 2h., which is 23·8′ (call it 24′) on top of column, and 1h. 42m. (that is, 60m. and 42m.) in left-hand margin, take out the corresponding proportional parts.

These two parts added together will give the correction, as under :—

24 at top of column, and 60m. in margin gives 12
24 ,, ,, 42m. ,, ,, 8

sum =20

which agrees with the calculated correction.

Correct the Moon's Semi-diameter.—Copy down the semi-diameter for the day of the G.M.T. from page ii of the month in the *Nautical Almanac* (it is given for 0 hrs.), and correct it for the hours and minutes of the G.M.T. as shown in the worked examples. The difference between the semi-diameters for the day of the G.M.T. and that for the following day is the " variation in 1 day." Turn the hours of the G.M.T. into the decimal part of a day by affixing a cipher to them and dividing the result by 24. The correction is obtained by multiplying the variation in 1 day by this decimal figure. It must be added if the semi-diameter is increasing, subtracted

if it is decreasing. It is always very small and of no practical value. If you are pressed for time, use the semi-diameter for the day which is nearest to your actual G.M.T. without making any correction for the daily variation. A correction called the "augmentation" must, however, be applied to it. This is taken from Table D in Norie's Tables, and must always be added.

Correct the Horizontal Parallax.—This is given in the *Nautical Almanac* in the column alongside the semi-diameter column, and is copied down for the day of the G.M.T., and corrected in exactly the same way as the semi-diameter. A correction called the "reduction" must then be applied to it. This is taken from Table E in Norie's Tables, and must always be subtracted. The approximate latitude must first be found as shown in the worked examples.

Find the True Altitude.—Write down the observed altitude as given in the question, and apply corrections to it as follows :—

Index error (if any), ...	According to its sign.
Dip, ...	Always subtract. } Same as for
Refraction, ...	Always subtract. } the sun.
Corrected semi-diameter, . . .	Add if lower limb is observed, subtract if upper limb is observed.
Parallax in altitude, ...	Always add.

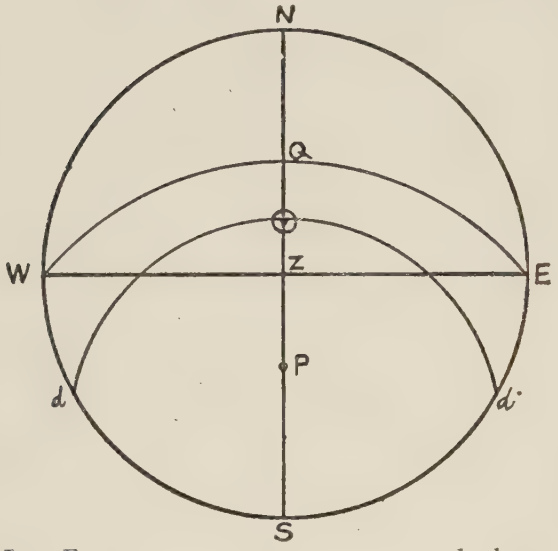
The log cosine of the altitude (after applying the semi-diameter) added to the common log of the horizontal parallax (in minutes) gives the common log of the parallax in altitude—*i.e.*,

Parallax in altitude = horizontal parallax × cosine altitude.

To find the Latitude.—Subtract the true altitude from 90° to get the zenith distance. Underneath the zenith distance write down the corrected declination; then if they have the same names add them together, but if different names subtract one from the other. The result is the latitude, which is found and named in the same way as when working a meridian altitude of sun or star.

Worked Example I.

On 27th April, 1929, in longitude 150° 20′ E., the observed meridian altitude of the moon's upper limb was 63° 48′ North of the observer, index error 1′ to subtract, height of eye 40 feet. Required the latitude.



This figure is constructed in precisely the same way as that for the meridian altitude of sun and star.

The circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
$N\,Z\,S$ the observer's meridian.
$W\,Z\,E$ the prime vertical.
$W\,Q\,E$ the equinoctial.
P the elevated pole.
$d \odot d'$ the parallel of declination.
$\odot$ the moon on the meridian.
$N \odot$ the altitude.
$Z \odot$ the zenith distance.
$Q \odot$ the declination.

From the figure it is seen that $Z \odot + \odot Q = Z\,Q$ or zenith distance + declination = latitude.

Long. E.			d.	h.	m.
150° 20′		Mer. pass., 27th, . =		02	23
4		Corr. for long. E., −			20
6,0) 60,1 20		S.M.T., . .	27	02	03
		Long. E., . . −		10	01·3
10h. 1m. 20s.					
10h. 1·3m.		G.M.T., . .	26	16	01·7
10h.					

	°	′		′
Decl. 26d. 16h., . =	22	52·2 S.	Var. 2h., =	15·2
Corr. ·03h., . +		·2 S.	Var. 1h., =	7·6
				·03
Corr. decl., .	22	52·4 S.		
				·228

Diff. 48 — 10 — 6) 480 — 4) 80 — 20

Semi-diameter.

27th = 14·8′ Var. 1 day ·1′
Corr., 0
14·8
Aug. + ·2
15·0

Horizontal Parallax.

			Var. 1 day ·2′
27th	=	54·4′	
Corr.	+	·1	·3
		54·5	·06
Red.	−	·1	
		54·4	

	°
Approx. alt., ...	64 N.
	90
Zen. dist., ...	26 S.
Declination, ...	23 S.
Approx. lat., ...	49 S.

	°	′	
Obs. alt., ...	63	48	N.
Ind. error., ... −		1	
	63	47	
Dip., ... −		6·2	
	63	40·8	
Semi-diam., . . . −		15·0	
Appt. alt., ...	63	25·8	
Ref., ... −		·5	
	63	25·3	
Parallax, ... +		24·3	
True alt., ...	63	49·6	N.
	90	00	
Zen. dist., ...	26	10·4	S.
Corr. decl., ...	22	52·6	S.
Latitude, ...	49	03·0	S.

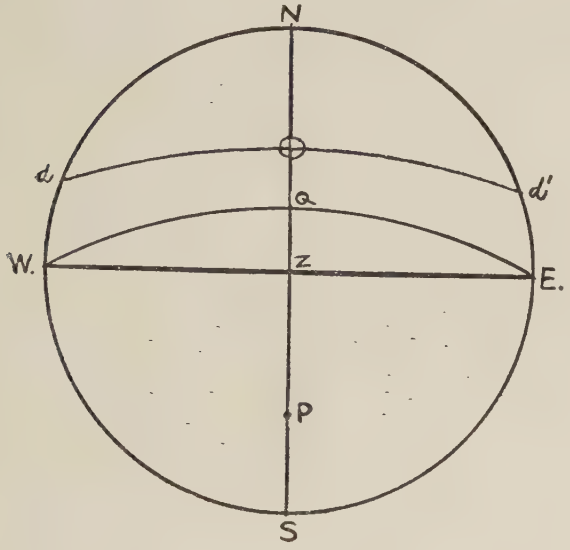
To Find the Parallax in Altitude.

Appt. alt. 63° 26′	log. cos. 9·65054
Hor. plx. 54·4	log. 1·73560
24·3′	log. 1·38614

When taking out the log cosine of the apparent altitude for finding the parallax in altitude it is only necessary to use the first five figures; the same remark applies to the common log of the horizontal parallax.

Worked Example II.

On 21st January, 1929, in longitude 125° 36′ W., the observed meridian altitude of the moon's L.L. was 35° 12′ North of the observer, height of eye 30 feet, index error 50″ to add. Required the latitude.



The circle represents a stereographic projection of the celestial sphere on the plane of the observer's rational horizon.

Z the observer's zenith.
$N\,Z\,S$ the observer's meridian.
$W\,Z\,E$ the prime vertical.
$W\,Q\,E$ the equinoctial.
P the elevated pole.
$d \odot d'$ the parallel of declination.
$\odot$ the moon on the meridian.
$N \odot$ the altitude.
$Z \odot$ the zenith distance.
$Q \odot$ the declination.
$Z\,Q$ the latitude.

From the figure it is seen that $Z \odot - Q \odot = Z\,Q$ or zenith distance — declination = latitude.

		d.	h.	m.
Long. W.	Mer. pass. 21st, . =		20	47
125° 36′	Corr. for long. W. +			22
4				
	S.M.T., . .	21	21	09
6,0) 50,2 24	Long. W. +		8	22·4
8h. 22m. 24s.	G.M.T., . .	22	05	31·4
8h. 22·4m.				
8·4h.				

	d.	h.	°	′	
Decl.,	22	04 =	24	39·9 N.	Var. 2h. = 12·3
Corr., 1·5h.		+		9·2	Var. 1h. = 6·15
					1·5
Corr. decl.,			24	49·1 N.	3075
					615
					9·225

	°
Approx. alt., ...	36 N.
	90
Zenith dist., ...	54 S.
Declination, ...	25 N.
Approx. lat., ...	29 S.

To Find the Parallax in Altitude.

Appt. alt. 35° 24′	log. cos. 9·91123
Hor. plx. 60·4′	log. 1·78104
49·2′	log. 1·69227

Diff. 63m
8·4
252
504
6) 529·2
4) 88·2
22

Semi-Diameter.

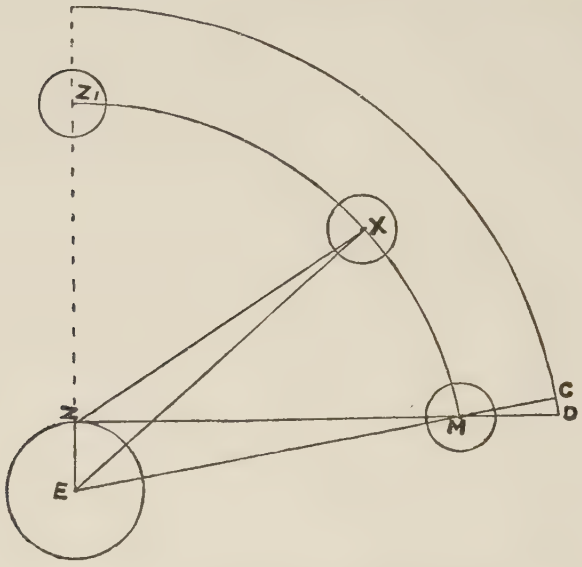
22nd,	= 16·4′	Var. 1 day, ·1
Corr.,	0	·2
	16·4	·02
Aug.	+ ·2	
	16·6	

Horizontal Parallax.

22nd	= 60·4′	Var. 1 day ·2′
Corr.,	0	·2
	60·4	·04
Red.,	0	
	60·4	

		°	′	
Obs. alt., ...		35	12	N.
Ind. error, ...	+		·8	
		35	12·8	
Dip.	−		5·4	
		35	07·4	
Semi-dia., ...	+		16·6	
Appt. alt., ...		35	24·0	
Ref., ...	−		1·3	
		35	22·7	
Parallax, ...	+		49·2	
True alt., ...		36	11·9	N.
		90	00	
Zenith dist., . . .		53	48·1	S.
Declination, . . .		24	49·1	N.
Latitude, ...		28	59·0	S.

Proof of Formula for finding Parallax in Altitude.



In figure :—E represents the centre of the earth, Z an observer, $Z\ M$ the sensible horizon, M the centre of the moon on the sensible horizon, X the centre of the moon with altitude $X\ Z\ M$.

From the observer's position at Z the moon at M would appear to be at D, but from E it would appear to be at C, therefore angle $C\ M\ D$ or $Z\ M\ E$ is the parallax when the moon is horizontal to the observer's zenith. Angle $Z\ M\ E$, therefore, represents the horizontal parallax.

Similarly, angle $Z\ X\ E$ is the parallax for apparent altitude $X\ Z\ M$—*i.e.*, parallax in altitude.

As the altitude increases so the parallax decreases until the moon reaches Z' with an altitude of 90°, when the parallax is nothing.

In right-angled triangle $Z\ E\ M$, $\frac{Z\ E}{E\ M} = \sin\ Z\ M\ E$ (which is the sine of the horizontal parallax.

By the "rule of sines" in oblique plane trignometry, the sines of angles are proportionate to their opposite sides, therefore :—

In oblique-angled triangle $Z\ E\ X$, $\frac{Z\ E}{E\ X} = \frac{\sin Z\ X\ E}{\sin E\ Z\ X}$.

Now $E\ M$ is equal to $E\ X$, $\therefore\ \frac{Z\ E}{E\ M} = \frac{Z\ E}{E\ X}$.

It has been shown that $\frac{Z\ E}{E\ M} =$ sin horizontal parallax.

Therefore $\frac{Z\ E}{E\ X} =$ sin horizontal parallax $= \frac{\sin Z\ X\ E}{\sin E\ Z\ X}$.

Sin $Z\ X\ E =$ sin parallax in altitude.

Sin $E\,Z\,X$ = cosine $X\,Z\,M$ (its complement), which is the apparent altitude, $\therefore$ sin $E\,Z\,X$ = cosine apparent altitude.

We then have from the above :—Sin horizontal parallax $= \dfrac{\text{sin plx. in alt.}}{\text{cos appt. alt.}}$

As the horizontal parallax and the parallax in altitude are very small angles, their sines are nearly proportional to the angles. We can, therefore, do away with the sines from both sides of the equation, leaving only the angles. We then have :—

$$\text{Horizontal parallax} = \frac{\text{plx. in alt.}}{\text{cos appt. alt.}}$$

from which, by transposing, we get :—

Horizontal parallax $\times$ cos appt. alt. = parallax in altitude.

Examples for Exercise XXIII.

(1) On 26th April, 1929, in longitude 60° W., the observed meridian altitude of the moon's L.L. was 55° 29′ North of the observer, height of eye 35 feet. Required the latitude.

(2) On 22nd January, 1929, in latitude 80° E., the observed meridian altitude of the moon's upper limb was 34° 20′ North of the observer, height of eye 65 feet, index error 2′ 30″ to subtract. Required the latitude.

(3) On 17th January, 1929, in longitude 150° 30′ W., the observed meridian altitude of the moon's L.L. was 45° 41′ South of the observer, height of eye 42 feet. Required the latitude.

(4) On 27th April, 1929, in longitude 140° 21′ E., the observed meridian altitude of the moon's upper limb was 63° 09′ South of the observer, index error 2′ 00″ to subtract, height of eye 70 feet. Required the latitude.

(5) On 23rd June, 1929, in longitude 20° W., the observed meridian altitude of the moon's upper limb was 63° 15′, the observer being North of the moon, index error 1′ 30″ to add, height of the eye 45 feet. Required the latitude.

(6) On 23rd January, 1929, on the meridian of Greenwich, the observed meridian altitude of the moon's L.L. was 61° 05′ South of observer, index error 1′ 00″ to subtract, height of eye 40 feet. Required the latitude.

NAPIER'S DIAGRAM.

Facing the next page a Napier's diagram has been inserted. By drawing a curve on it as explained further on, we obtain a graphic deviation card.

The form of the papers which are set at the examinations are the same as drawn out in these examples.

Compass bearings of a distant object are given which are supposed to have been taken with the ship's head on eight equi-distant points by compass. The points chosen are the cardinal and quadrantal ones.

The mean of these eight compass bearings gives the magnetic bearing of the object.

The difference between each compass bearing and this magnetic bearing is the deviation for the direction of the ship's head when the bearing was taken.

Having found the eight deviations, they are entered in the " deviation required " column as shown in the worked examples.

In the questions as set at the examination, this column is left blank, and in it the candidate is required to enter up the deviations which he has found.

These deviations are then laid off on a Napier's diagram, and a flowing line drawn through the points indicated by them. This line forms a curve of deviations, and is really a deviation card represented in graphic form.

The deviations often come out much larger than would be expected on a properly adjusted compass. There are reasons for this. One is that the compass may not have been adjusted, another that the ship may have undergone large structural alterations since the last adjustment, or that the deviations may be caused by the cargo with which she is loaded at the time of being swung.

To find the Magnetic Bearing of the Object.

If all the bearings have the same names, add them together and divide the sum by eight.

If some are named N. and the others named S., subtract each of the Northerly ones separately from 180° and change its name to Southerly ; or each of the Southerly ones from 180° and change its name to Northerly. All of the bearings will then be reckoned from North or from South. Add them together and divide the sum by eight.

If some of the bearings are named E. and the others named W., find the sum of the Easterly bearings, also of the Westerly bearings, subtract the lesser sum from the greater, and divide by eight.

Worked Example I.

Having taken the following bearings of a distant object by the standard compass, find the magnetic bearing of the object and thence the deviations :—

Ship's head by standard compass.	Bearing of object by standard compass.	Deviation required.	Ship's head by standard compass.	Bearing of object by standard compass.	Deviation required.
North	N. 46° E.	7° E.	South	N. 62° E.	9° W.
N.E.	N. 25° E.	28° E.	S.W.	N. 76° E.	23° W.
East	N. 24° E.	29° E.	West	N. 79° E.	26° W.
S.E.	N. 43° E.	10° E.	N.W.	N. 69° E.	16° W.

138
286
8)424
N. 53 E.

286

Magnetic bearing required :—N. 53° E.

After finding the magnetic bearing, write it down on the paper in the place marked for it, and proceed to find the deviation on each point by taking the difference between the magnetic bearing and each compass bearing, as follows :—

To Find the Deviations.

	N.	N.E.	E.	S.E.	S.	S.W.	W.	N.W.
Magnetic bearing,	N. 53° E.	N. 53° E.	N. 53° E.	N. 53° E.	N. 53° E.	N. 53° E.	N. 53° E.	N. 53° E.
Compass bearings,	N. 46 E.	N. 25 E.	N. 24 E.	N. 43 E.	N. 62 E.	N. 76 E.	N. 79 E.	N. 69 E.
Deviations, . .	7° E.	28° E.	29° E.	10° E.	9 W.	23° W.	26° W.	16° W.

The rule for naming these deviations is similar to that for naming the error in azimuths and amplitudes. That is—

If the magnetic is to the right of the compass bearing the dev. is East.

If the magnetic is to the left of the compass bearing the dev. is West.

After finding these deviations (which you can do mentally if you like) place them in the column marked " deviation required."

To Construct the Curve with the Foregoing Deviations.

(See thin curve on diagram.)

The vertical line on the diagram (called the mesial line) represents the margin of the compass, and the dots are degrees.

The deviation on North is 7° E. With the dividers measure 7° from anywhere on the mesial line, and with one leg of the dividers on North lay this off on the dotted line through North on the East side of the diagram (see the names East and West at the top of the diagram). Mark the point where it comes to ○. Do the same with the deviations on the other points, being careful to always lay them off along the dotted lines on their proper sides, Westerly deviations being laid off on the left side of the diagram. The deviation on North must be laid off at the bottom as well as at the top of the vertical line.

Then draw a regular curve passing through each of these points. In the event of it being impossible to draw a fair curve that will pass exactly through all the points, draw it as near to them as possible, in order that a fair and even curve may be constructed.

To Turn Magnetic Courses into Compass Courses.

Place one leg of the dividers on the vertical line at the given magnetic course and the other at the point where the plain line through it (or a line parallel to the plain lines) cuts the curve. Then keep the leg on the curve fixed, and move the one on the vertical line round until it meets the vertical line again, they will then be parallel with the dotted lines, and the point where the leg is on the vertical line is the compass course.

Suppose the magnetic course to be E. by N., placing one leg of the dividers on E. by N., go out with the other along the plain line through E. by N. to the point where it cuts the curve. Then, keeping this latter leg fixed, move the other until the dividers are parallel with the dotted lines, you will then find they meet the vertical line at N. 50° E. This is the compass course.

By proceeding in a similar manner with the following magnetic courses you will obtain compass courses very nearly the same as given below,

Magnetic courses, .	E. by N.	W.S.W.	S.W. $\frac{1}{2}$ S.	E. by S. $\frac{1}{2}$ S.
Comp. courses required,	N. 50° E.	N. 87° W.	S. 65° W.	N. 75$\frac{1}{2}$° E.

Lines are drawn on the diagram to assist you in following out the above rule. Always put your answers in degrees as above.

To turn Compass Courses into Magnetic Courses.

The rule is exactly the reverse to the last one. That is, go out along or parallel to the dotted lines and return parallel to the plain lines.

Suppose the compass course to be N.N.E. Placing one leg of the dividers on N.N.E., go out along the dotted line through N.N.E. and place the other leg at the point where it cuts the curve. Keep this leg on the curve fixed and move the other so that they are parallel to the plain lines, you will then find the leg of dividers on the vertical line at N. 43° E. Proceeding in the same manner with the others you will obtain.

Compass courses,	N.N.E.	S.W. by S.	N.W. $\frac{1}{2}$ N.	S.E by E. $\frac{1}{4}$ E.
Mag. courses required,	N. 43° E.	S. 14° W.	N. 52° W.	S. 42° E.

The following rhyme is often used as an aid to memory :—

From compass course magnetic course to gain
Depart by dotted and return by plain,
But when a course magnetic is allotted
Depart by plain, return by dotted.

To turn Compass Bearings into Magnetic Ones.

Note the direction of the ship's head. Place one leg of the dividers on this point and the other on the curve parallel to the dotted lines. The distance in the dividers is the deviation for the direction of the ship's head. Notice its name and then remove them, being careful they do not open or close, and place one leg of the dividers on the given compass bearing and with the other :—

Measure down the vertical line if the deviation for ship's head is Easterly.
„ up „ „ „ „ „ Westerly.
The point where it reaches is the magneitc bearing.

Suppose the ship's head to be N.E. by E., and the compass bearings South, and W. by S.

Placing one leg of the dividers on N.E. by E., and going out on the dotted line until the other leg is on the curve, we get the deviation in the dividers, and its name is East.

Removing the dividers from N.E. by E. (being careful not to open or close them) we place one leg on South, the first compass bearing, and then because the deviation for ship's head was Easterly we measure downwards, and find the magnetic bearing to be S. 30° W. Do exactly the same with the other, and arrange the answers as follows :—

Compass bearings, ...	South.	W. by S.
Magnetic bearings required, . .	S. 30° W.	N. 72° W.

If the deviation for the direction of the ship's head had been Westerly we should have measured upwards from the two compass bearings. This is sometimes remembered by means of the expression " up the West end."

Worked Example II.

When some of the bearings are Easterly and others Westerly.

Take the sum of the Easterly bearings and the sum of the Westerly bearings separately; subtract the less from the greater and divide the difference by 8. The result is the magnetic bearing to be named the same as the greater.

Having taken the following compass bearings of a distant object, find its magnetic bearing, and thence the deviations :—

Magnetic bearing required—S. 5° E.

Ship's head by standard compass.	Bearing of distant object by standard compass.	Deviation required.	Ship's head by standard compass.	Bearing of distant object by standard compass.	Deviation required.
North	S. 13° W.	18° W.	South	S. 32° E.	27° E.
N.E.	S. 21° W.	26° W.	S.W.	S. 39° E.	34° E.
East	S. 23° W.	28° W.	West	S. 25° E.	20° E.
S.E.	S. 1° E.	4° W.	N.W.	S. 3° E.	2° W.

Sum of Easterly bearings = S. 100 E.
Sum of Westerly bearings = S. 57 W.

8)43

Magnetic bearing, S. 5 E. same as the greater.

Next proceed to find the deviations, which can easily be done mentally, being careful to add where the magnetic and compass bearings are of different names. You will then obtain the deviations as in the columns above.

With the deviations as above, construct a curve on Napier's diagram, and give the courses you would steer by compass in order to make the following courses correct magnetic. *See* thick curve on the diagram.

Magnetic courses, .	N.E. by N.	E. by S.	S.W. ½ W.	W. by N.
Compass courses required,	N. 63° E.	S. 63° E.	S. 17° W.	S. 76° W.

You should follow these on the diagram, and see that you obtain the same answers as given here.

Suppose you have steered the following courses by standard compass, find the magnetic courses made from the above curve of deviations.

Compass courses, .	East.	West.	N.N.E. ½ E.	N. by E.
Magnetic courses required,	N. 61° E.	N. 70° W.	N. 6° E.	N. 9° W.

When working near the North point, as in the last of the above courses, fold the diagram round so as to bring the N. point at the bottom of the vertical line over the N. point at the top.

You have taken the following bearings of two distant objects by your standard compass with the ship's head at S.S.W., find the magnetic bearings.

Compass bearings, ...	E.N.E.	N.N.W.
Magnetic bearings required, . .	S. 78° E.	N. 11° E.

The courses and bearings should come within a degree or so of the answers given above.

Examples for Exercise XXIV.

(1) You have taken the following compass bearings of a distant object. Find its magnetic bearing, and thence the deviation on those points on which the bearings were observed.

Ship's head by standard compass.	Bearing of object by standard compass.	Deviation required.	Ship's head by standard compass.	Bearing of object by standard compass.	Deviation required.
North	S. 75° W.		South	S. 34° W.	
N.E.	S. 64° W.		S.W.	S. 31° W.	
East	S. 56° W.		West	S. 49° W.	
S.E.	S. 50° W.		N.W.	S. 71° W.	

Magnetic bearing required :—

With the deviations as above, construct a curve on a Napier's diagram, and give the courses you would steer by the standard compass in order to make the following courses magnetic :—

Magnetic courses, . . N.N.W. S. 22° E. N. 68° W. E.S.E.

Compass courses required,

Supposing you have steered the following courses by the standard compass, find from the above-mentioned curve of deviations, the corresponding magnetic courses.

Compass courses . . N. 22° E. N. 67° E. S. 23° W. S. 67° W.

Magnetic courses required,

You have taken the following bearings of two distant objects by your standard compass with the ship's head N.E. $\frac{1}{2}$ E. by compass. Find the magnetic bearings.

Compass bearings, . . . S.E. by S. N.N.W.

Magnetic bearings required, . .

The following examples are not given in full, as the foregoing example is sufficient to show the method and order in which this problem is always set at the examinations.

(2)

Ship's head by standard compass.	Bearing of distant object by standard compass.	Deviation required.	Ship's head by standard compass.	Bearing of distant object by standard compass.	Deviation required.
North	S. 20° E.		South	S. 2° W.	
N.E.	S. 26° E.		S.W.	S. 6° W.	
East	S. 18° E.		West	S. 1° W.	
S.E.	S. 2° E.		N.W.	S. 5° E.	

Magnetic bearing required :—

Magnetic courses, . N.N.E E.N.E. S.S.E W.N.W.
Compass courses required,

Compass courses, . N.E. by E. S.W. by W. N.W. by N. N. $\frac{1}{4}$ W.
Magnetic courses required,

Ship's head at West, objects bore as follows :—

Compass bearings, . . . N.E. N.W.
Magnetic bearings required, . .

(3)

Ship's head by standard compass.	Bearing of distant object by standard compass.	Deviation required.	Ship s head by standard compass.	Bearing of distant object by standard compass.	Deviation required.
North	N. 3° E.		South	N. 3° W.	
N.E.	N. 17° W.		S.W.	N. 9° E.	
East	N. 20° W.		West	N. 21° E.	
S.E.	N. 15° W.		N.W.	N. 22° E.	

Magnetic bearing required :—

Magnetic courses, . N. by E. $\frac{1}{2}$ E. S.E. by S. $\frac{1}{2}$ S. S.W. $\frac{3}{4}$ W. N. $\frac{1}{4}$ W.
Compass courses required,

Compass courses, . . N. 78° E. S.E. $\frac{1}{4}$ S. S.W. $\frac{3}{4}$ S. E. $\frac{1}{4}$ N.
Magnetic courses required,

Ship's head at N.E. $\frac{1}{2}$ E., objects bore as follows :—

Compass bearings, . . . E. $\frac{3}{4}$ S. N. $\frac{1}{4}$ W.
Magnetic bearings required, . .

(4)

Ship's head by standard compass.	Bearing of distant object by standard compass.	Deviation required.	Ship's head by standard compass.	Bearing of distant object by standard compass.	Deviation required.
North	N. 57° E.		South	N. 50° E.	
N.E.	N. 35° E.		S.W.	N. 64° E.	
East	N. 31° E.		West	N. 75° E.	
S.E.	N. 39° E.		N.W.	N. 74° E.	

Magnetic bearing required :—

Magnetic courses, . E.N.E. E.S.E. W.S.W. W.N.W.
Compass courses required,

Compass courses, . E. by N. S.E. by E. W.S.W. N.W by N.
Magnetic courses required,

Ship's head East by compass, objects bore as follows:—

Compass bearings, . . . N.N.E. W. by N.
Magnetic bearings required . .

Using Napier's Diagram in the Chartwork.

Candidates may be required to find the compass courses (also magnetic courses if compass courses are given) and correct the compass bearings by means of a curve of deviations drawn on a Napier's diagram.

A deviation card may be given to them to enable them to construct the curve, or they may have to find the magnetic bearing and thence the deviations from compass bearings of an object, and construct the curve as already explained.

These bearings are generally taken (as shown in the preceding examples) with the ship's head on different points **by compass**, in which case the deviations are laid off on the dotted lines.

If they are taken with the ship's head on different points **magnetic**, the resulting deviations must be laid off on the diagram on the **plain** lines.

Having drawn the curve, magnetic courses are turned into compass courses (and *vice versa*), and compass bearings into magnetic bearings, in exactly the same way as shown in the preceding examples.

Compass bearings may be turned into **true** ones by taking the **error** of the compass in the dividers and using it in the same way that the deviation was used to find the magnetic bearings.

One or two of the chart examples should be worked in this way—that is to say, the courses and bearings should be corrected by means of a curve of deviations drawn on a Napier's diagram.

GREAT CIRCLE SAILING.

When candidates have to do a Great Circle problem, either the paper on meteorology or the essay will be omitted.

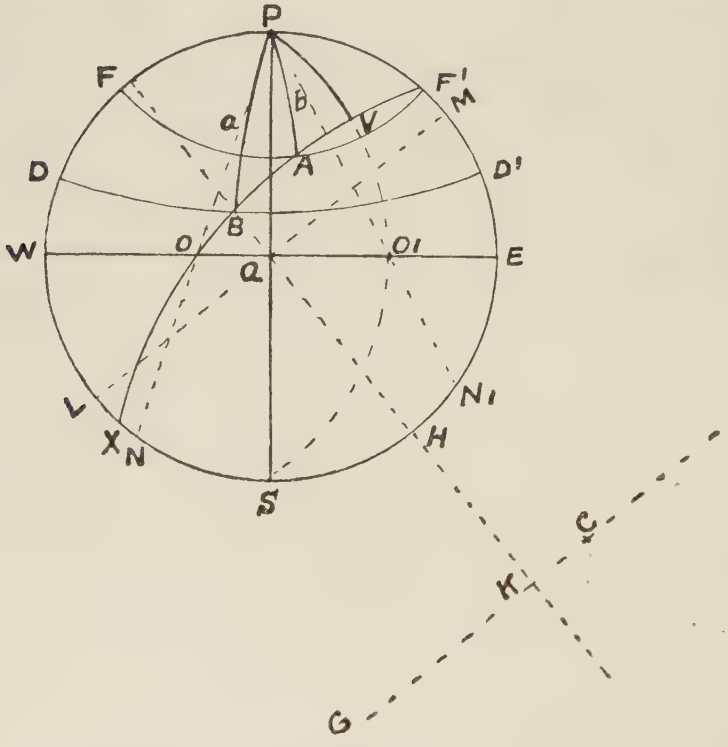
Read through the essay on the subject before you start on the working of the problems.

Worked Example I.

Find the initial and final courses, also the distance on the great circle, from Honolulu in latitude 21° 18′ N., longitude 157° 52′ W., to a point off Vancouver Island in latitude 48° 34′ N., longitude 126° 4′ W. Required also the lat. and long. of the vertex and the latitude of the points where the great circle cuts the meridian of 150° W., and thence every 10° of longitude to destination.

To construct the Figure.

Draw the circle $P\,E\,S\,W$ to represent a stereographic projection of the earth's sphere on the plane of the meridian, then P and S represent the north and south poles respectively and $W\,Q\,E$ the equator.



The place which is nearest to the pole is named A, the other place being called B.

To put in the parallel of latitude of A, make arc $W\,F$ equal the latitude of A, which is about 49°. A line from F to E indicates the point where the parallel of latitude 49° cuts the meridian. Find the centre of the circle passing through F and this point. This will be somewhere on the meridian (extended if necessary), draw in the circle $F\,A\,F'$, and this will be the parallel of latitude of A.

The parallel of latitude B is described in the same manner; this is represented by $D\,B\,D'$ in the figure.

To draw in the meridians of A and B, let $P\,Q\,S$ be the meridian that is midway between them, then we must place these meridians at half their difference of longitude on each side of $P\,Q\,S$. The difference of longitude between A and B is 32°, the meridians $P\,A$ and $P\,B$ are, therefore, put 16° from $P\,Q\,S$. This is done in precisely the same way as when describing the hour circle in the time-azimuth problem, P being the pole and $W\,Q\,E$ the locus line.

These meridians intersect their respective parallels of latitude at B and A, which are the points of departure and destination respectively.

The side opposite angle A will be small a, and is the co-lat. of the place B. Similarly, the side opposite angle B is small b, and is the co-lat. of place A.

If the two places are in latitudes of different name, work from the pole which is nearest to the place having the highest latitude, and remember that one side of your triangle $P\ A\ B$ will be more than 90°.

The initial course must be named the same as the pole you are working from, and the final course opposite to the pole you are working from, also E. or W. the same as in Mercator's sailing. **Look at your figure.**

To put in the great circle passing through A and B, draw the diameter $B\ Q\ H$ and another diameter $L\ Q\ M$ at right angles to it (both through Q). Find the centre of the great circle that will pass through $L\ B$ and M, and through this centre draw a line at right angles to $B\ Q\ H$ ($G\ K\ C$ in figure), this is the locus line for point B, all great circles passing through B will have their centres somewhere on $G\ K\ C$. On this line find the centre of the great circle passing through B and A (point C), then with C as centre and $C\ B$ as radius, describe the great circle $X\ B\ A\ F'$. The arc of this great circle included between B and A represents the great circle track between B and A.

The vertex of the great circle $X\ B\ A\ F'$ is found as follows:—Draw the line $P\ O\ N$ through O, the point where the great circle crosses the equator, and make arc $N\ N' = 90°$. Draw a line from N' to P, this crosses the equator at O', which is the position where the meridian of the vertex also crosses the equator. Draw in the meridian of the vertex $P\ O'\ S$. This crosses the great circle $X\ B\ A\ F'$ at V, which is the required vertex.

EXPLANATION OF THE FIGURE.

(To be written at the examination.)

The circle $P\ E\ S\ W$ represents a stereographic projection of the terrestrial sphere on the plane of the meridian.

P and S, the poles of the earth.
$P\ Q\ S$, the central meridian between B and A.
$W\ Q\ E$, the equator.
B, the point of departure.
A, the point of destination.
$D\ B\ D'$, parallel of latitude B.
$F\ A\ F'$, parallel of latitude A.
$B\ P$, the co-lat. of B.
$A\ P$, the co-lat. of A.
$B\ P\ A$, the diff. of longitude between B and A.
$X\ B\ A\ F'$, the great circle passing through B and A.
V, the vertex of the great circle.
$P\ B\ A$, the initial course.
$P\ A\ B$, the final course.
Arc $B\ A$, the great circle track.

In the figures for both the worked examples, all the lines used in the construction of the figures are included for the benefit of the student. The only parts which must be shown at the examination are those mentioned in the above explanation. The other constructional lines, which should be drawn with a pencil, may be erased when the diagram is completed.

The second figure, used for finding the position of the points on the great circle, may be drawn approximately by estimation, the first figure being a very good guide to its construction.

Worked Example I.

To find the Distance.

Given in triangle $P\,A\,B$ the sides $P\,A$ and $P\,B$ and the angle P (the difference of longitude between A and B).

Required to find side $B\,A\,(p)$ = the distance.

Formula :—

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (P\,A \sim P\,B)}{\sin P\,A \sin P\,B}.$$

Hav. P sin $P\,A$ sin $P\,B$ = hav. p − hav. $(P\,A \sim P\,B)$
Hav. P sin $P\,A$ sin $P\,B$ + hav. $(P\,A \sim P\,B) = p$.

Long. A, 126° 4′ W.
Long. B, 157 52 W.
31° 48′ = P

P = 31° 48′	log. hav.	8·87537
$P\,A$ = 41 26	log sin	9·82069
$P\,B$ = 68 42	log sin	9·96927
	log hav.	8·66533
	nat. hav.	0·04627
$(P\,A \sim P\,B)$ = 27° 16′	nat. hav.	0·05556
	nat. hav.	0·10183

Lat. A 48° 34′ N., co-lat. 41° 26′ = $P\,A$ (b).
Lat. B 21 18 N., co-lat. 68 42 = $P\,B$ (a).
$P\,A \sim P\,B$ = 27° 16′.

p = 37° 13·2′
60
Distance, 2,233·2 miles.

To find angle B (the initial course).

$$\text{Hav. } B = \frac{\text{hav. } b - \text{hav. } (B\,A \sim B\,P)}{\sin B\,A \sin B\,P}.$$

b = 41° 26′	nat. hav.	0·12514
$(B\,A \sim B\,P)$ = 31 28·8	nat. hav.	0·07359
	nat. hav.	0·05155
	log hav.	8·71221
$B\,A$ = 37° 13·2′	log cosec	0·21833
$B\,P$ = 68 42	log cosec	0·03073
35° 12·5′	log hav.	8·96127

Initial course, N. 35° 12·5′ E.

To find angle A (the final course).

$$\text{Hav. } A = \frac{\text{hav. } a - \text{hav. } (A\,B \sim A\,P)}{\sin A\,B \sin A\,P}.$$

a = 68° 42′	nat. hav.	0·31837
$(A\,B \sim A\,P)$ = 4 12·8	nat. hav.	0·00135
	nat. hav.	0·31702
	log hav.	9·50109
$A\,B$ = 37° 13·2′	log cosec	0·21833
$A\,P$ = 41 26	log cosec	0·17931
125° 44′	log hav.	9·89873

Final course, S. 125° 44′ E.
or N. 54 16 E.

If angles A and B are both acute—that is, both less than 90°—the vertex of the great circle will be **inside** the triangle, but if either of them are over 90° it will be outside the triangle. In this case angle A is over 90°, and, therefore, V is on the great circle **outside** the triangle $P\,A\,B$, as shown in the diagram.

To find the Lat. and Long. of the Vertex.

FOR THE LATITUDE.

Given in triangle $P\ A\ V$ the side b and angle A.
Required to find side $P\ V$ (co-lat. of vertex).
By Napier's rules :—

Sin $P\ V$ = cos comp b cos comp A.
Sin $P\ V$ = sin b sin A.

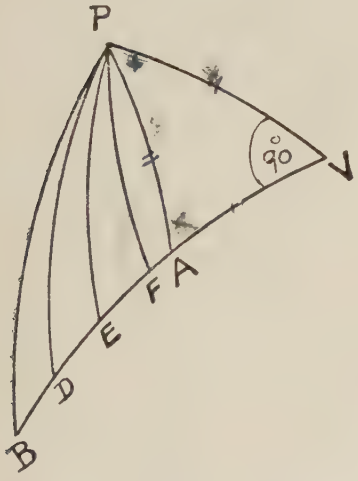
b = 41° 26′	log sin	9·82069
A = 54 16	log sin	9·90942
	log sin	9·73011
$P\ V$ = 32° 29·5′		
90 00		
Lat. vertex 57° 30·5′ N.		

FOR THE LONGITUDE.

In triangle $P\ A\ V$, **given** the same parts.
Required to find the angle $A\ P\ V$.
By Napier's rules :—

Sin comp b = tan comp A — tan comp $A\ P\ V$
Cos b = cot A — cot $A\ P\ V$
Cos b × tan A = cot $A\ P\ V$

b = 41° 26′	log cos	9·87490
A = 54 16	log tan	0·14300
	log cotan	10·01790
$A\ P\ V$ = 43° 49′		
Long. A = 126 04 W.		
Long. vertex 82° 15′ W.		



To find the Latitude of Points 10° of Longitude apart.

Let D be the first point in Long. 150° W.

Then in triangle $P\ D\ V$, **given** side $P\ V$ and angle $D\ P\ V$.*

Required to find side $P\ D$ = co-lat. of D.

By Napier's rules :—

Sin comp $D\ P\ V$ = tan $P\ V$	tan comp $P\ D$
∴ cos $D\ P\ V$ = tan $P\ V$	cot $P\ D$
i.e., cos $D\ P\ V$ × cot $P\ V$	=tan lat D
or cos $D\ P\ V$ × tan lat V	=tan lat D

The same formula holds good for the other points by giving the proper value to the polar angles.

Long. D = 150° 0′ W.		
Long. V = 82 15 W.		
P = 67° 45′	log cos	9·57824
Lat. V = 57 30·5	log tan	0·19595
	log tan	9·77419
Lat. D = 30° 44′ N.		

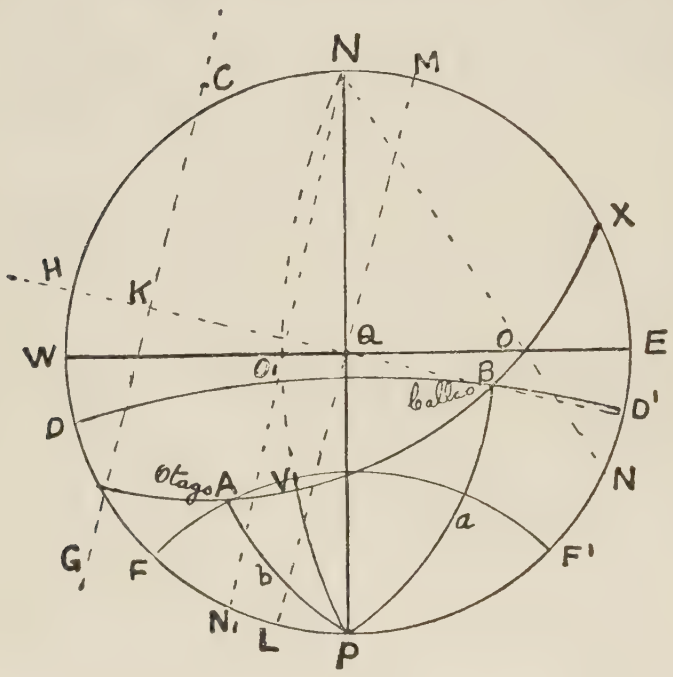
Long. E = 140° 0′ W.		
Long. V = 82 15 W.		
P = 57° 45′	log cos	9·72723
Lat. V = 57 30·5	log tan	0·19595
	log tan	9·92318
Lat. E = 39° 57·5′ N.		

Long. F = 130° 0′ W.		
Long. V = 82 15 W.		
P = 47 45	log cos	9·82761
Lat. V = 57 30·5	log tan	0·19595
		10·02356
Lat. F = 46° 33′ N.		

* $D\ P\ V$ is the angle at P between $P\ D$ and $P\ V$, and is, therefore, the difference of longitude between D and V. When working out the latitudes of the points, this angle changes with their longitude. It is generally termed "P."

Worked Example II.

Find the initial and final courses and the distance on the great circle from Otago Harbour, Tairoa Head, in latitude 45° 47′ S., longitude 170° 45′ E., to Callao, in latitude 12° 4′ S., longitude 77° 14′ W. Required also, the lat. and long. of the vertex and the position of a succession of points along the great circle at a distance of 10° of longitude apart, beginning with a point in longitude 172° 54′ E.



A. Lat. 45° 47′ S. . co-lat. 44° 13′ = *P A* (*b*)
B. Lat. 12 4 S. . co-lat. 77 56 = *P B* (*a*)

P A ~ *P B* = 33° 43′

Explanation of figure is the same as in the preceding example.

Given in triangle *P A B* the sides *P A* and *P B* and the angle *P*.

Required to find side *A B* (*p*) the distance.

Formula :—

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (P A \sim P B)}{\sin P A \sin P B}$$

Hav. *P* sin *P A* son *P B*
= hav. *p* — hav. (*P A* ~ *B*.
Hav. *P* sin *P A* sin *P B*
+ hav. (*P A* ~ *P B*) = hav. *p*.

P = 112° 1′	log hav.	9·83723
P A = 44 13	log sin	9·84347
P B = 77 56	log sin	9·99030
	log hav.	9·67100
	nat. hav.	0·46881
(*P A* ~ *P B*) = 33° 43′	nat. hav.	0·08410
p = 96° 4·4′	nat. hav.	0·55291
60		

Distance, 5764·4 miles.

To find angle *A* (the initial course).

$$\text{Hav. } A = \frac{\text{hav. } a - \text{hav. } (A B \sim A P)}{\sin A B \sin A P}.$$

a = 77° 56′	nat. hav.	0·39548
A B ~ *A P* = 51 51·4	nat. hav.	0·19119
	nat. hav.	0·20429
	log hav.	9·31024
A B = 96° 4·4′	log cosec	0·00245
A P = 44 13	log cosec	0·15653
65° 44·7′	log hav.	9·46922

Initial course, S. 65° 45′ E.

To find angle *B* (the final course).

$$\text{Hav. } B = \frac{\text{hav. } b - \text{hav. } (B A \sim B P)}{\sin B A \sin B P}.$$

b = 44° 13′	nat. hav.	0·14165
B A ~ *B P* = 18 8·4	nat. hav.	0·02485
	nat. hav.	0·11680
	log hav.	9·06746
B A = 96° 4·4′	log cosec	0·00245
B P = 77 56	log cosec	0·00970
40° 33·4′	log hav.	9·07961

Final course, N. 40° 33′ E.

To find the Lat. and Long. of the Vertex.

FOR THE LATITUDE.

Given in triangle $P\ A\ V$ the side b and angle A.
Required to find side $P\ V$ (co-lat. of vertex).

By Napier's rules :—

Sin $P\ V$ = cos comp b cos comp A
Sin $P\ V$ = sin b sin A

b = 44° 13′	log sin	9·84347
A = 65 45	log sin	9·95988
$P\ V$ = 39 29	log sin	9·80335
90 0		

50° 31′ S. = Lat. of vertex.

FOR THE LONGITUDE.

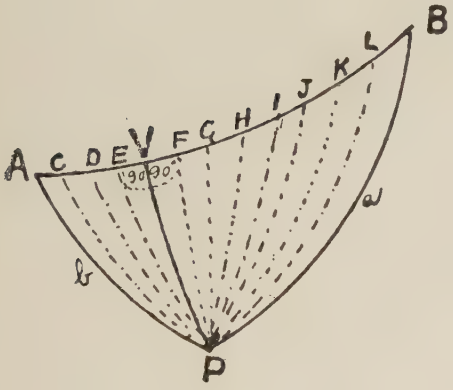
In triangle $P\ A\ V$, given the same parts.
Required to find angle $A\ P\ V$.

By Napier's rules :—

Sin comp b = tan comp A tan comp $A\ P\ V$
Cos b = cot A cot $A\ P\ V$
Cos b × tan A = cot $A\ P\ V$

b = 44° 13′	log cos	9·85534
A = 65 45	log tan	0·34634
$A\ P\ V$ = 32 9	log cot	0·20168
Long. A = 170 45 E.		
202° 54′		
360 0		

Long. of vertex, 157° 6′ W.



To find the Latitude of Points 10° of Longitude Apart.

Let C be the first point in long. 172° 54′ E.

Then in triangle $P\ C\ V$, **given** side $P\ V$ and angle P.

Required to find side $P\ C$ = co-lat. of C.

By Napier's rules :—

Sin comp P = tan $P\ V$ tan comp $P\ C$
∴ cos P = tan $P\ V$ cot $P\ C$
i.e., cos P × cot $P\ V$ = cot $P\ C$
or cos P × tan lat V = tan lat C

Long. C = 172° 54′ E.
Long. V = 157 6 W.

330° 0′
360 0

P =	30° 0′	log cos	9·937531
Lat. V =	50 31	log tan	10·084153
		log tan	10·021684

Lat. C = 46° 26′ S.

Long. D = 177° 6′ W.
Long. V = 157 6 W.

P =	20° 0′	log cos	9·972986
Lat. V =	50 31	log tan	10·084153
		log tan	10·057139

Lat. D = 48° 45½′ S.

Long. E = 167° 6′ W.
Long. V = 157 6 W.

P =	10° 0′	log cos	9·993351
Lat. V =	50 31	log tan	10·084153
		log tan	10·077504

Lat. E = 50° 5′ S.

Points F, G, and H will have the same latitudes as E, D, and C respectively, because their polar angles are the same (on the other side of the vertex).

The latitudes of points I, J, K, and L are found by the same formula as all the others (working not shown).

I.	Lat. 42° 55′	S.,	Long. 117° 5½′	W.
J.	Lat. 37 37½	S.,	Long. 107 5½	W.
K.	Lat. 31 15	S.,	Long. 97 5½	W.
L.	Lat. 22 33	S.,	Long. 87 5½	W.

Examples for Exercise XXV.

(1) Find the initial and final courses and the distance on the great circle from a position South of the Lizard (latitude 49° 50′ N., longitude 5° 12′ W.) to a point off Barbadoes (latitude 13° 6′ N., longitude 59° 20′ W.). Give also, the latitude and longitude of the vertex and the latitudes of a succession of points 10° of longitude apart through which the great circle will pass, commencing with a point in longitude 15° 12′ W.

(2) Find the initial and final courses and the distance on the great circle from a position (*B*) in latitude 36° 55′ N., longitude 140° W., to a point (*A*) in latitude 51° 40′ N., longitude 170° E. Also required the latitude and longitude of the vertex and the latitudes of the points where the track crosses the meridian of 150° W., and thence every 10° of longitude to destination.

(3) Required the initial and final courses and the distance on the great circle from Algoa Bay, Lat. 34° 2′ S., Long. 25° 30′ E., to Cape Comorin, Lat. 8° 9′ N., Long. 78° 6′ E. Give the position of the vertex and the latitude in which the great circle crosses each 10th degree of longitude, beginning at the meridian of 35° 30′ E.

(4) Required the initial and final courses and the distance along the arc of a great circle from the Cape of Good Hope in latitude 34° 22′ S., longitude 18° 29′ E., to a position off the Straits of Sunda in latitude 6° 40′ S., longitude 104° 29′ E. Find also, the latitude and longitude of the vertex and the latitudes of a succession of points where the great circle cuts the meridian of 10° of longitude to the Eastward of the vertex, and thence every 10° of longitude to destination.

COMPOSITE SAILING.

When candidates are given a problem in Composite Sailing, either the paper on meteorology or the essay will be omitted. The essay on the subject (to be found in this book) will give candidates a general idea of the problem and its object and advantage.

Though rather long, it is quite simple and easy to understand, the whole of the working being done by right angled spherical trigonometry and one case of parallel sailing.

The figure is constructed on the same principle as that for great circle sailing.

The work should be done as follows:—

Draw the circle to represent the earth.

Put in the parallel of maximum latitude.

Draw (in pencil) the parallels of latitude of the points of departure and destination.

Mark (in pencil) the approximate position of the points of departure and destination.

Put in the meridians representing their co-latitudes.

(Draw in pencil) the arcs of the two great circles, one passing through the point of departure and touching the maximum latitude, and the other passing through the point of destination and touching the maximum latitude.

The points where these great circles touch the maximum latitude are the vertices of those great circles. Put in the two meridians representing the co-latitudes of the vertex.

You then have two right-angled spherical triangles, the right angles being at the point where the meridians representing the co-latitude touch the parallel of maximum latitude (and the great circles).

In one of these triangles you have given the co-lat. of the vertex and the co-lat. of point of departure, and in the other the co-lat. of the vertex and the co-lat. of the point of destination.

Work out the initial course which is the angle at the point of departure, and the final course which is the angle at the point of destination. The initial course must be named the same as the pole you are working from, and the final course opposite to the pole you are working from.

Work out the distance on each of the great circles.

Find the longitudes of the two vertices.

All the above mentioned calculations are done by Napier's Rules as shown in the following worked examples.

Find (by parallel sailing) the distance along the arc of the parallel of maximum latitude. **The total distance** along the composite route is found by adding together the distance along the arc of each of the great circles and that along the arc of the parallel of maximum latitude contained between them.

The latitudes of the points along the track are then found by Napier's Rules.

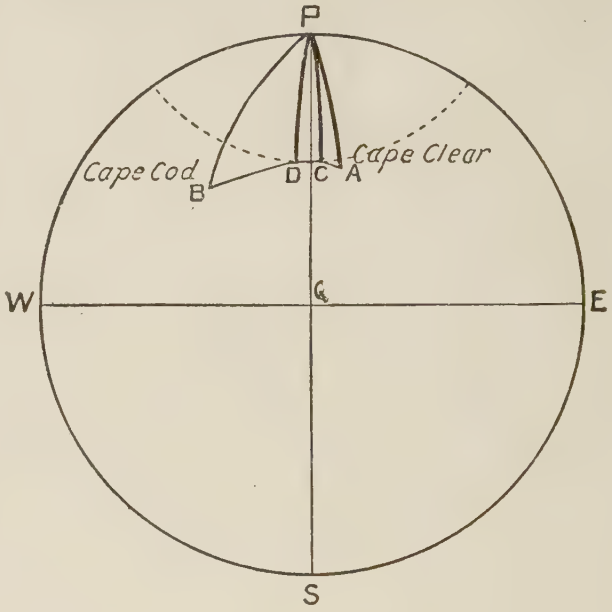
The "longitude from vertex" is the angle at the pole contained between the meridian passing through the vertex and the meridian passing through the point. In other words, it is the difference of longitude between the vertex and the points, and is generally called *P*.

The track may be laid down on a Mercator's chart by plotting off the positions of the points along the great circles and drawing a fair curve through them. The course and distance from one to the next may then be calculated by Mercator's sailing. The arc of the parallel of latitude will appear as a straight line.

COMPOSITE GREAT CIRCLE SAILING.

Worked Example I.

Required the composite track from Cape Cod in Lat. 42° 2′ N., Long. 70° W. to Cape Clear in Lat. 51° 25′ N., Long. 9° 32′ W., the maximum latitude to be 52° N. Find the longitudes at which the track meets and leaves that latitude, also the initial and final great circle courses and the total distance along the composite track. Required also the longitude from vertex and the latitudes at which the track crosses the meridian of 60° W. and thence every 10° of longitude to destination.



The circle represents a stereographic projection of the earth on the plane of the meridian, *P* the North pole, *W Q E* the equator.

B D the arc of a great circle passing through Cape Cod and touching the maximum latitude. *D* is its vertex.

C A the arc of another great circle passing through Cape Clear and touching the maximum lat. *C* is its vertex.

The arc *D C* is an arc of the parallel of maximum latitude.

The three arcs together form the composite track.

B, Lat. 42° 2′ N. . co-lat. 47° 58′ = *P B*
A, Lat. 51 25 N. . co-lat. 38 35 = *P A*

Lat. *D*, 52° 0′ N. . co-lat. 38° 0′ = *P D*
Lat. *C*, 52 0 N. . co-lat. 38 0 = *P C*

To find the initial course

Given in triangle *B P D* the sides *P B* and *P D*
Required to find angle *B*

Sin *P D* = cos comp *P B* cos comp *B*
Sin *P D* = sin *P B* sin *B*
Sin *P D* × cosec *P B* = sin *B*

P D = 38° 0′ log sin 9.789342
P B = 47 58 log cosec 0.129154
log sin 9.918496

Initial course N. 55° 59′ 5″ E.

To find the final course

Given in triangle *A P C* the sides *P A* and *P C*
Required to find angle *A*

Sin *P C* = cos comp *P A* cos comp *A*
Sin *P C* = sin *P A* sin *A*
Sin *P C* × cosec *P A* = sin *A*

P C = 38° 0′ log sin 9.789342
P A = 38 35 log cosec 0.205058
log sin 9.994400

Final course S. 80° 49′ 6″ E.

To find side *B D* (distance on first great circle)
Given in triangle *B P D* the sides *P B* and *P D*
Required to find side *B D*

Sin comp *P B* = cos *P D* cos *B D*
Cos *P B* × sec *P D* = cos *B D*

P B = 47° 58′ log cos 9.825791
P D = 38 0 log sec 0·103468
log cos 9.929259

B D = 31° 49′ 21″
60
B D = 1909·3 miles

To find side *C A* (distance on second great circle)
Given in triangle *A P C* the sides *P A* and *P C*
Required to find side *C A*

Sin comp *P A* = cos *P C* cos *C A*
Cos *P A* × sec *P C* = cos *C A*

P A = 38° 35′ log cos 9·893041
P C = 38 0 log sec 0·103468
log cos 9·996509

C A = 7° 15′ 19″
60
C A = 435·3 miles

Worked Example I.—(*Continued*).

To find the longitude of D
(point where track meets maximum latitude).

Given in triangle $B\,P\,D$ the sides $P\,B$ and $P\,D$

Required to find angle $B\,P\,D$

Sin comp $B\,P\,D$ = tan comp $P\,B$ tan $P\,D$
Cos $B\,P\,D$ = cot $P\,B$ tan $P\,D$

$P\,B$ = 47° 58′	log cot	9·954946
$P\,D$ = 38 0	log tan	9·892810
	log cos	9·847756

$B\,P\,D$ = 45° 13′ 38″
Long. B = 70 0 0 W.

Long. D = 24 46 22 W

To find the longitude of C
(point where track leaves maximum latitude).

Given in triangle $A\,P\,C$ the sides $P\,A$ and $P\,C$

Required to find angle $A\,P\,C$

Sin comp $A\,P\,C$ = tan $P\,C$ tan comp $P\,A$
Cos $A\,P\,C$ = tan $P\,C$ cot $P\,A$

$P\,C$ = 38° 0′	log tan	9·892810
$P\,A$ = 38 35	log cot	0·098099
	log cos	9·990909

$A\,P\,C$ = 11° 40′ 58″
Long. A = 9 32 0 W.

Long. C = 21 12 58 W

To find the total distance.

Distance = $B\,D + D\,C + C\,A$

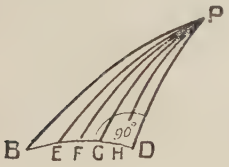
Long. D = 24° 46′ 22″ W.
Long. C = 21 12 58 W.

$D\,C$ = 3 33 24
60

D. long. 213·4

$D\,C$ = D long. ×	cos max. lat.	$B\,D$ = 1909·3	miles
Lat. 52° 0′	log cos 9·789342	$D\,C$ = 131·4	,,
D. long. 213·4	log 2.329194	$C\,A$ = 435·3	,,
131·4	log 2·118536	Distance 2476·0	miles

To find the latitude of the points along the track.



Let E be the first point in longitude 60° W. Then in triangle $E\,P\,D$ we have **given** the side $P\,D$ and the angle P

Required to find side $P\,E$.

Sin comp P = tan $P\,D$ tan comp $P\,E$.
Cos P = tan $P\,D$ tan comp $P\,E$.

or cos polar angle × tan max. lat. = tan lat. E.

The same formula holds good for the other points by giving the proper values to the polar angles.

Long. E = 60° 0′ 0″ W
Long. D = 24 46 22 W.

P = 35 13 38	log cos	9·912153	
Max. lat. = 52 0 0	log tan	0·107190	
	log tan	0·019343	

Lat. E = 46° 16′ 32″ N.

P = 25° 13′ 38″	log cos	9·956468	
52 0 0	log tan	0·107190	
	log tan	0·063658	

Lat. F = 49° 11′ 3″ N.

P = 15° 13′ 38″	log cos	9·984478	
52 0 0	log tan	0·107190	
	log tan	0.091668	

Lat. G = 51° 0′ 9″ N.

P = 5° 13′ 38″	log cos	9·998190	
52 0 0	log tan	0·107190	
	log tan	0.105380	

Lat. H = 51° 53′ 3″ N.

Long. J = 20° 0′ 0″ W.
Long. C = 21 12 58 W

P = 1 12 58	log cos	9·999902	
52 0 0	log tan	0·107190	
	log tan	0·107092	

Lat. J = 51° 59′ 37″ N.

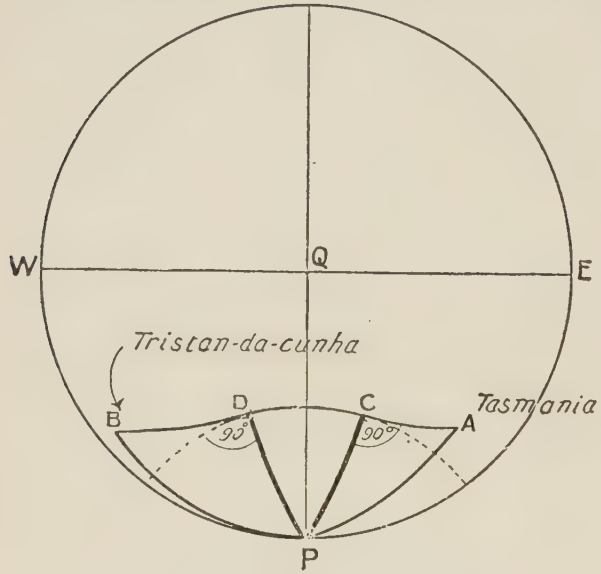
P = 11° 12′ 58″	log cos	9·991625	
52 0 0	log tan	0·107190	
	log tan	0·098815	

Lat. K = 51° 27′ 46″ N.

COMPOSITE GREAT CIRCLE SAILING.

Worked Example II.

Required the composite route from Tristan da Cunha in lat. 37° 3′ S., long. 12° 18′ W. to Tasmania in lat. 44° S., long 145° E., the maximum lat. to be 52° S. Find the longitudes at which the ship must meet and leave that latitude, also the initial and final great circle courses and the total distance along the composite track. Required also the longitude from vertex and the latitudes at which the track crosses the meridian of 20° E. and thence every 10° of longitude to destination.



The circle represents a stereographic projection of the earth on the plane of the meridian, *P* the South pole, *W Q E* the equator.

B D is the arc of a great circle passing through Tristan da Cunha and touching the maximum latitude. *D* is its vertex.

C A is the arc of another great circle passing through the destination and touching the maximum latitude. *C* is its vertex.

The arc *D C* is an arc of the parallel of maximum latitude.

The three arcs together form the composite track.

B, Lat. 37° 3′ S. co-lat. 52° 57′ = *P B*
A, Lat. 44 0 S. co-lat. 46 0 = *P A*

Lat. *D* 52° 0′ S. co-lat. 38° 0′ = *P D*
Lat. *C* 52 0 S. co-lat. 38 0 = *P C*

To find the initial course

Given in triangle *B P D* the sides *P B* and *P D*
Required to find angle *B*.

Sin *P D* = cos comp *P B* cos comp *B*
Sin *P D* = sin *P B* sin *B*
Sin *P D* × cosec *P B* = sin *B*

P D = 38° 0′	log sin	9·789342
P B = 52 57	log cosec	0·097937
	log sin	9·887279

Initial course S. 50° 28′ 47″ E.

To find the final course

Given in triangle *A P C* the sides *P A* and *P C*
Required to find angle *A*

Sin *P C* = cos comp *P A* cos comp *A*
Sin *P C* = sin *P A* sin *A*
Sin *P C* × cosec *P A* = sin *A*

P C = 38° 0′	log sin	9·789342
P A = 46 0	log cosec	0·143066
	log sin	9·932408

Final course N. 58° 51′ 21″ E.

To find side *B D*

(distance on first great circle)

Given in triangle *B P D* the sides *P B* and *P D*
Required to find side *B D*

Sin comp *P B* = cos *P D* cos *B D*
Cos *P B* × sec *P D* = cos *B D*

P B = 52° 57′	log cos	9·779966
P D = 38 0	log sec	0·103468
	log cos	9·883434

40° 7′ 43″
60

B D = 2407·7 miles

To find side *C A*

(distance on second great circle)

Given in triangle *A P C* the sides *P A* and *P C*
Required to find side *C A*

Sin comp *P A* = cos *P C* cos *C A*
Cos *P A* × sec *P C* = cos *C A*

P A = 46° 0′	log cos	9·841771
P C = 38 0	log sec	0·103468
	log cos	9·945239

28° 10′ 19″
60

C A = 1690·3 miles.

Worked Example II.—(*Continued*).

To find the longitude of D

Given in triangle $P\,B\,D$ the sides $P\,B$ and $P\,D$
Required to find angle $B\,P\,D$

Sin comp $B\,P\,D$ = tan comp $P\,B$ tan $P\,D$
Cos $B\,P\,D$ = cot $P\,B$ tan $P\,D$

$P\,B$ = 52° 57′	log cot	9·877903	
$P\,D$ = 38° 0′	log tan	9·892810	
	log cos	9·770713	
$B\,P\,D$ = 53° 51′ 23″			
Long. B = 12 18 0 W			
Long. D = 41 33 23 E			

To find the longitude of C

Given in triangle $A\,P\,C$ the sides $P\,A$ and $P\,C$
Required to find angle $A\,P\,C$

Sin comp $A\,P\,C$ = tan $P\,C$ tan comp $P\,A$
Cos $A\,P\,C$ = tan $P\,C$ cot $P\,A$

$P\,C$ = 38° 0′	log tan	9·892810	
$P\,A$ = 46 0	log cot	9·984837	
	log cos	9·877647	
$A\,P\,C$ = 41° 1′ 12″			
Long. A = 145 0 0 E.			
Long. C = 103 58 48 E			

To find distance along parallel of maximum latitude

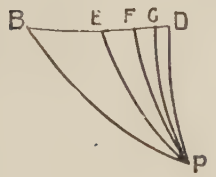
Long. D = 41° 33′ 23″ E	$D\,C$ = D. long. × cos. lat.		
Long. C = 103 58 48 E	Lat. 52° 0′	log cos	9·789342
62 25 25	3745·4	log	3·573498
60	2305·9	log	3·362840
D. long = 3745·4			

To find the total distance

Total distance = $B\,D + D\,C + C\,A$

$B\,D$ =	2407·7 miles
$D\,C$ =	2305·9 ,,
$C\,A$ =	1690·3 ,,
Distance	6403·9 miles

To find the lat. of the points along the track.



Let E be the first point in long. 20° E., then in triangle $E\,P\,D$ we have **given** the side $P\,D$ and the angle P.
Required to find side $P\,E$.

Sin comp P = tan $P\,D$ tan comp $P\,E$
Cos P = tan $P\,D$ tan comp $P\,E$

or Cos polar angle × tan maximum lat. = tan lat. point E.

The same formula holds good for the other points when the proper value is given to each polar angle.

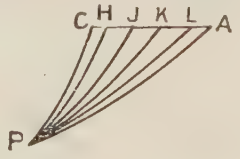
Long. E = 20° 0′ 0″ E.			
Long D = 41 33 23 E.			
P = 21 33 23	log cos	9·968509	
Max. lat. = 52 0 0	log tan	0·107190	
	log tan	0·075699	
Lat. E 49° 58′ 6″ S.			

Long. F = 30° 0′ 0″ E.			
Long. D = 41 33 23 E.			
P = 11 33 23	log cos	9·991106	
Max. lat. = 52 0 0	log tan	0·107190	
	log tan	10·098296	
Lat. F = 51° 25′ 46″ S.			

Long. G = 40° 0′ 0″ E.			
Long. D = 41 33 23 E.			
P = 1 33 23	log cos	9·999839	
Max. lat. = 52 0 0	log tan	0·107190	
	log tan	10·107029	
Lat. G 51° 59′ 23″ S.			

Long. H 110° 0′ 0″ E.			
Long. C 103 58 48 E.			
P = 6 1 12	log cos	9·997598	
Max. lat. = 52 0 0	log tan	0·107190	
Lat. H = 51° 50′ 46″ S.	log tan	10·104788	
P = 26° 1′ 12″	log cos	9·953587	
52 0 0	log tan	0·107190	
	log tan	10·060777	
Lat. K = 48° 59′ 46″ S.			

There are six points on the parallel of maximum lat.



Long. J. 120° 0′ 0″ E.			
Long. C 103 58 48 E.			
P = 16 1 12	log cos	9·982798	
Max. lat. = 52 0 0	log tan	0·107190	
Lat. J = 50° 53′ 38″ S.	log tan	10·089988	
P = 36° 1′ 12″	log cos	9·907848	
52 0 0	log tan	0·107190	
	log tan	10·015038	
Lat. L = 45° 59′ 30″ S.			

COMPOSITE GREAT CIRCLE SAILING.

Examples for Exercise XXVI.

(1) Required the initial and final courses and the distance along the composite great circle route from Wellington Isle (lat. 49° 7′ S., long. 75° 50′ W.) to New Zealand (lat. 45° 54′ S., long. 170° 46′ E.) the maximum latitude to be 55° S. Find the longitude of the points where the track meets and leaves the maximum latitude, also the longitude from vertex and the latitudes of the points where the track crosses the meridian of 80° W. and thence every 10° of longitude to destination.

(2) Required the initial and final courses and the distance along the composite route from the East Coast of Japan (lat. 35° 40′ N., long. 141° E.) to a point off San Francisco (lat. 37° 48′ N., long. 122° 40′ W.), the ship not to go higher than latitude 45° N. Find the longitude of the points where the track meets and leaves the maximum latitude, also the longitude from vertex and the latitudes of the point where the track intersects the meridians passing through the 150th degree of East longitude and every 10° of longitude in succession until arriving off San Francisco.

Note.—Read your question very carefully (especially at the examination) and make up your mind definitely as to what you are required to do. If you are only told to find the initial course, do not work out the final one. The questions in great circle sailing (composite and otherwise) may be varied considerably. Many marks are lost at the exams. by reason of carelessness, generally through not answering the question properly. The writing and figuring must be neat. Write the answer down clearly so that the examiner will have no trouble to understand it. Untidy work means a loss of marks. See that you do not go to leeward on that account.

The problems in some cases would be rather more useful and practical if the latitudes of the points along the arc of the *second* great circle were worked by making their longitudes 10°, 15° or 20° (or whatever the question stated) from the longitude of the vertex in the second triangle. This would have the advantage of doing away with any odd minutes in the second lot of polar angles, and there would be no possibility of the first point in the second triangle being so close to the vertex that its latitude would be practically the same as that of the vertex. There would not be any change whatever in the formula.

Up to the time of going to press, this has not been required. It may however, be asked for at any time. Be careful.

THE PLANETS.

The sun is the centre of the Solar system. There are eight satellites of the sun which are called planets and which move round him in elliptical orbits. Given in the order of their distance from the sun they are as follows:—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune. A belt of Asteroids lies in between the orbits of Mars and Jupiter. There are also a large number of asteroids relatively near to the sun. Mercury lies too near the sun to be often visible to the naked eye, Uranus and Neptune are also very difficult to pick up as being so far distant from the earth they only appear as small stars. Some particulars of the planets:—

	Distance from Sun.	Revolves round Sun in	Satellites, etc.
Venus	67 million miles	225 days	none
Earth	93 ,,	365¼ days	one (the moon)
Mars	141 ,,	687 days	two
Jupiter	482 ,,	11 yrs. 314 days	four
Saturn	884 ,,		eight, also three rings
Uranus	1768 ,,		
Neptune	2562 ,,		

The declinations of Venus, Mars, Jupiter and Saturn are always between 30° N. and 30° S., the highest declination of any of them during 1925 is that of Venus which reaches 26° 26.8′ S. on the 8th of November.

All types of problems which candidates are accustomed to working with the stars as the observed objects can also be worked with the planets when they are available in a good position.

Planets are not suitable at times for meridian altitudes or ex-meridians as when they are on or near the meridian during daylight they are generally barely visible or not visible at all on account of the strong light of the sun. Also, at night time a planet may be showing brilliantly (as may a star) but on account of the difficulty in getting a good horizon observations of either of them may not be reliable. When they can be observed under favourable circumstances they should be used. As in the case of the stars, morning or evening twilight is the best time for observation as during those periods the horizon is most clearly defined. Practice with, and make yourself efficient in the use of the inverting telescope; it will often enable you to determine the horizon properly when you cannot do so with the ordinary star glass. Star binoculars are now often used.

The planets most used by navigators are Venus and Jupiter. Venus revolves round the sun on an orbit inside that of the earth, and for that reason is called an inferior planet. Being near the sun (never more than about 47° E. or W. of it) she may be observed in the morning or evening but is not visible throughout the night in these latitudes. She is commonly called the morning or evening star. The same term is applied to Jupiter when he shows brilliantly in the morning or evening. The orbits

of Mars, Jupiter and Saturn are outside that of the earth. They are called superior planets and it is possible for them to be visible at any time of the night. Mars is of a ruddy colour and Saturn is of a yellowish hue. These two are not so bright as Venus and Jupiter.

Semi-diameter and parallax.—Planets have an *apparently* small diameter and semi-diameter, and for strict accuracy their altitude should be corrected for semi-diameter and parallax. The correction for semi-diameter would not be necessary if the planet's *centre* could be observed. The value of both, however, is negligible, and not being given in the abridged edition of the *Nautical Almanac* need not be used at the examinations.

The calculations when a planet is used differ from problems worked with a star in one way only.

As their Right Ascension and Declination are subject to considerable change, they must both be corrected for the Greenwich mean time of observation.

Hence, in the meridian altitude we must find the M.T.G. when the planet is on the meridian of the ship so that we may correct its declination for that time.

The time of the meridian passage of a planet is found on the same principle as is the meridian passage of the moon. An explanation and examples are given two pages ahead. The correction for longitude is never more than $2\frac{1}{2}$ minutes for 180° of longitude, and being so small it may be omitted for practical work. It should, however, be calculated as a matter of principle at the examinations.

It must be noticed that in the *Nautical Almanac* the given time of the meridian passage is reckoned from midnight, while the R.A. and Decl. are given at Greenwich mean noon on each day. Go over the worked examples very carefully. The astronomical figures have not been given, as they are exactly the same as for the star problems and candidates are already thoroughly familiar with him. The object has been given the name of *X* throughout.

MERIDIAN PASSAGE OF A PLANET.

The calculation to find the time of the meridian passage of a planet over the meridian of the ship is based on the same principle as that of the meridian passage of the moon as previously explained. The working is done as follows:—

Write down the time of the meridian passage for the day of the question. This will be found on pages XI and XII of the month in the *Nautical Almanac*, and is also given in this book.

In another place (to the right of it) write the time of this meridian passage down again. Underneath it write down the time of the preceding meridian passage if the longitude is East, but the following one if the longitude is West.

Find the difference between them.

Multiply this difference by the longitude in time and divide the product by 24. This gives a "correction for longitude" which must be applied to the time of the meridian passage first written down.

If the second meridian passage which you wrote down (to find the difference) is greater than the first one this correction must be added; if it is smaller this correction must be subtracted. The result is the Mean time at ship when the planet is on the meridian.

Apply to this the longitude in time, East subtract, West add, to get the Mean time at Greenwich.

Worked Example I.

On 2nd January, 1929, at ship, in longitude 128° 30′ W., find the Mean time at Greenwich when the planet *Mars* will be on the meridian.

Long. W. 128° 30′ 4

6,0) 51,4 0

8h. 34m. 0s.
8h. 34·0m.
8·6h.

	d.	h.	m.
Mer. pass. of Mars	2	22	49
Corr. for longitude, −			1·8
S.M.T.,	2	22	47·2
Longitude W., +		8	34·0
G.M.T.,	3	07	21·2

	h.	m.
Mer. pass. 2nd	= 22	49
Mer. pass. 3rd	= 22	44
		5
		8·6
		6) 43·0
		4) 7·2
		1·8

Worked Example II.

On 31st January, 1929, in longitude 145° 40′ E., find the Mean time at Greenwich when the planet *Venus* will be on the meridian.

Long. E. 145° 40′ 4

6,0) 58,2 40

9h. 42m. 40s.
9h. 42·7m.
9·7h.

	d.	h.	m.
Mer. pass. of Venus	31	15	10
Corr. for longitude, +			·4
S.M.T.,	31	15	10·4
Longitude E., −		9	42·7
G.M.T.,	31	05	27·7

	h.	m.
Mer. pass. 31st.	= 15	10
Mer. pass. 30th	= 15	11
		1
		9·7
		6) 9·7
		4) 1·6
		·4

Worked Example III.

On 4th August, 1929, at ship, in longitude 176° 40′ W., required the Mean time at Greenwich when the planet *Saturn* will be on the meridian.

Long. W. 176° 40′ 4

6,0) 70,6 40

11h. 46 m. 40s.
11h. 46·7 m.
11·8h.

	d.	h.	m.
Mer. pass. of Saturn,	4	20	44
Corr. for longitude, −			2
S.M.T.,	4	20	42
Longitude W., +		11	46·7
G.M.T.,	5	08	28·7

	h.	m.
Mer. pass. 4th	= 20	44
Mer. pass. 5th	= 20	40
		4
		11·8
		6) 47·2
		4) 7·9
		2

Examples for Exercise XXVII.

In the following examples, required the Mean time at Greenwich when the planets named will be on the meridian of the ship on the given dates :—

(1) On 4th August, 1929, in longitude 44° 10′ E., Jupiter.
(2) On 4th August, 1929, in longitude 174° 18′ W., Jupiter.
(3) On 4th January, 1929, in longitude 125° 45′ E., Venus.
(4) On 4th January, 1929, in longitude 125° 45′ W., Venus.
(5) On 11th August, 1929, in longitude 128° 40′ E., Saturn.
(6) On 12th January, 1929, in longitude 53° 45′ W., Mars.

MERIDIAN ALTITUDE OF PLANET.

Worked Example I.

On 13th August, 1929, in latitude by account 44° S., longitude 170° 50′ W., compute the approx. obs. mer. alt. of the planet *Jupiter* as a guide to setting the sextant for observation. Index error of sextant 1′ 30″ to subtract, height of eye 34 feet.

Find the G.M.T. when the planet is on the meridian of the ship as previously explained.

Correct the declination for the G.M.T. It is given in the *Nautical Almanac* on pages xi. and xii. of the month for 0h., G.M.T. on every day.

Copy down the declination given for 0h. on the date of your G.M.T., and correct it for the remaining hours and decimal parts of an hour.

In this example the G.M.T. is 13d. 18h. 39·9m. The declination at 0h. on the 13th will therefore have to be corrected for 18·66h.—say 18·7 hrs.

Now copy down the number which is placed on a level midway between the declination you have copied down and the declination for the following day. This number represents the number of minutes which the declination has changed in 24 hours. Multiply this change by the hours and decimal parts of an hour in your G.M.T. (in this example 18·7h.) and divide the product by 24.

The result is the correction to apply to the declination already copied down. It must be added if the declination is increasing, but subtracted if it is decreasing. The result is the corrected declination.

The remainder of the work is exactly the same as in meridian altitude of a star. It is not necessary to correct the planet's altitude for semi-diameter or parallax.

Long. W.		d.	h.	m.		h.	m.		°	′		′
° ′	Mer. pass. .	13	07	18	13th = 7	18		Decl. 13th, . =	21	29·3	N.	1·1
170 50	Corr. for long., . −			1·4	14th = 7	15		Corr. 18·7h., +		·9		18·7
/ 4												
	S.M.T., . .	13	07	16·6		3		Corr. decl., .	21	30·2	N.	6) 20·57
6,0) 68,3 20	Long. W., . . +		11	23·3		11·4						
												4) 3·43
11h. 23m. 20s.	G.M.T. . .	13	18	39·9		6) 34·2						·86
11h. 23·3m.												
11·4h.						4) 5·7						
						1·4						

	°	′	
Lat. by acct., ...	44	0	S.
Decl., ...	21	30·2	N.
Appx. mer. zen. dist., . . .	65	30·2	S.
	90	0	
Appx. true alt., ...	24	29·8	N.
Refraction, ... +		2·1	
Dip, ... +		5·7	
Index error, ... +		1·5	
Appx. obs. mer. alt., . . .	24	39·1	N.

Worked Example II.

On 4th August, 1929, in longitude 166° 15′ E., the observed altitude of the planet *Saturn* on the meridian was 27° 18′ South of the observer, index error 1′ 00″ to add, height of eye 32 feet. Required the latitude.

Long. E.		d.	h.	m.		h.	m.			°	′
° ′	Mer. pass., . .	4	20	44	4th =	20	44	Decl. 4th, .	.=	22	13·2 S.
166 15	Corr. for long., .+			1·8	3rd =	20	48	Corr., . . .			0
4	S.M.T., . .	4	20	45·8			4	Corr. decl., . .		22	13·2 S.
6,0) 66,5 0	Long. E., . .−		11	5·0			11·1				
11h. 5m. 0s.	G.M.T., . .	4	09	40·8		6)	44·4				
11h. 5·0m.						4)	7·4				
11·1h.							1·8				

	°	′	
Obs. alt., ...	27	18	S.
Index error, ...+		1	
	27	19	
Dip, ...−		5·5	
	27	13·5	
Ref., ...−		1·8	
True alt., ...	27	11·7	
	90	0	
Zen. dist., ...	62	48·3	N.
Declination, ...	22	13·2	S.
Latitude, ...	40	35·1	N.

EXAMPLES FOR EXERCISE XXVIII.

(1) On 13th January, 1929, in lat. by acct. 12° 20′ N., long. 163° 35′ W., compute the approx. obs. mer. alt. of *Mars*, index error of sextant 1′ 30″ to subtract, height of eye 27 feet.

(2) On 27th January, 1929, in lat. by acct. 56° 20′ N., long. 151° 15′ E., compute the approx. obs. alt. of *Venus* when on the meridian, height of eye 26 feet, index error of sextant 2′ to add.

(3) On 3rd August, 1929, on the meridian of Greenwich, the obs. mer. alt. of *Jupiter* was 30° 06′ North of the observer, index error 1′ 30″ to add, height of eye 45 feet. Required the latitude.

(4) On 24th August, 1929, in longitude 6° W., the observed altitude of *Saturn* when on the meridian was 69° 50′ S. of observer, index error 30″ to subtract, height of eye 39 feet. Required the latitude.

LONGITUDE BY PLANET.

Worked Example.

On 5th August, 1929, in latitude by account 39° 38′ S., the observed altitude of *Saturn* was 27° 54′ West of the meridian, index error 1′ 30″ to add, height of eye 35 feet, time by a chronometer (4th August) 16h. 15m. 50s., which was 1m. 10s. slow of Mean time at Greenwich. Required the longitude by chronometer.

Find (from the chronometer) the G.M.T. at the time of observation.

Correct R, also the planet's R.A. and Decl. for the G.M.T. ; find $P X$ (the polar distance).

Correct the obs. alt. to find the true alt. and thence $Z X$ (the zenith dist.).

Work out the hour angle and find the longitude by exactly the same method as used in " Longitude by star."

	d.	h.	m.	s.
Time by chrontr., . . .	4	16	15	50
Slow, ... +			1	10
G.M.T., ...	4	16	17	00

	d.	h.	h.	m.	s.
R., ...	4	16	=20	50	54·9
Corr. 17m., . . .			+		2·8
R. corrected, . . .				20	50 57·7

	d.	h.	h.	m.	s.
R.A., . .	4	0	=17	35	45
Corr. 16·3h., .			—		7
R.A., . .			17	35	38

h. s.
change in 24=10
16·3

6) 163

4) 27

7

	°	′
Obs. alt., . .	27	54
Ind. err., . . +		1·5
	27	55·5
Dip, . . . —		5·8
	27	49·7
Ref., . . . —		1·8
True alt., . .	27	47·9
	90	0
Zen. dist., . .	62	12·1 = $Z X = p$

	d.	h.	°	′	
Decl., . .	4	0	=22	13·2	S.
Corr. 16·3h., . +				·1	
Corr. decl., .			22	13·3	S.
			90	0	
Polar dist., .			67	46·7 = $P X$	

h. m.
change in 24= ·1
16·3

6) 1·63

4) ·27

·07

	°	′
$P Z$	= 50	22
$P X$	= 67	46·7
$P Z \sim P X$	= 17	24·7

$$\text{Hav. } P = \frac{\text{hav. } p - \text{hav. } (P Z \sim P X)}{\sin P Z \sin P X}$$

	°	′	
p	= 62	12·1′	nat. hav. 0·26682
$P Z \sim P X$	= 17	24·7	nat. hav. 0·02291
			nat. hav. 0·24391
			log hav. 9·38723
$P Z$	= 50	22	log cosec 0·11343
$P X$	= 67	46·7	log cosec 0·03352
			log hav. 9·53418

P = 4h. 46m. 22s.

	h.	m.	s.
Planet's W'ly H.A., . .	4	46	22
Planet's R.A., . . +	17	35	38
R.A.M., ...	22	22	00
R., ... —	20	50	58
S.M.T., . . .	5	01	31	02
G.M.T., . . .	4	16	17	00
		9	14	2
		60		
	4) 554	2		
Longitude, . . .	138	30	30 E.	

Examples for Exercise XXIX.

1. On 2nd January, 1929, in latitude by account 45° 10′ N., the observed altitude of *Venus* was 11° 00′ West of the meridian, index error 3′ to subtract, height of eye 25 feet, a chronometer (corrected) indicated 20h. 20m. 00s. Mean time at Greenwich. Required the longitude by chronometer.

2. On 10th January, 1929, in latitude by account 55° N., the observed altitude of *Mars* was 34° 59′ East of the meridian, index error 1′ to subtract, height of eye 29 feet, a chronometer (corrected) indicated 22h. 28m. 40s. Mean time at Greenwich. Required the longitude by chronometer.

3. On 7th August, 1929, in latitude by account 35° 2′ S., when a chronometer which was fast of Mean time at Greenwich, 1m. 08s. indicated 07h. 21m. 08s., the observed altitude of *Jupiter* was 16° 05′ East of the meridian, height of eye 26 feet. Required the longitude by chronometer.

PLANET TIME AZIMUTH.

Worked Example I. (G.M.T. given).

On 5th August, 1929, in latitude 39° 36′ S., longitude 138° E., when a chronometer (corrected) indicated Mean time at Greenwich (4th August) 16h. 10m. 30s., the planet *Saturn* bore by compass S. 81° W. Required the true azimuth and error of the compass by the Time azimuth tables, and supposing the Variation to be 4° 40′ E., required the deviation of the compass for the direction of the ship's head.

Correct R., also the planet's R.A. and Decl. for the G.M.T.

Find the S.M.T., thence the R.A.M. and planet's hour angle.

With the latitude, planet's decl., and hour angle, take out the true azimuth from the tables. Name it the same as the latitude and same as the hour angle.

Finish in the same way as in Time azimuth by sun or star.

	d.	h.	m.	s.
G.M.T.,	4	16	10	30
Long. E., +		9	12	0
S.M.T.,	5	01	22	30
R., +		20	50	57
R.A.M.,		22	13	27
Planet's R.A.,		17	35	38
Hour angle,		4	37	49 W.

	d.	h.	h.	m.	s.
R.,	4	16	=20	50	54·9
Corr. 10·5m., +					1·7
R. corrected,			20	50	56·6

	d.	h.	m.	s
R.A.,	4	=17	35	45
Corr. 16·2h., −				7
R.A. corrected,		17	35	38

	d.	°	′	
Decl.,	4	=22	13·2	S.
Corr. 16·2h., +			·1	
Decl. corrected,		22	13·3	S.

s.
10
16·2
6) 162
4) 27
7

′
0·1
16·2
6) 1·62
4) ·27
·07

Lat. 39° . . . Decl. 22° . . .

°	°	h.	m.	°
Lat. 39	Decl. 22	H.A. 4	32	= 85·2
40	22	4	32	= 85·8
				·6
				·6
				+ ·36

°	°	h.	m.	°
Lat. 39	Decl. 22	H.A. 4	32	= 85·2
39	23	4	32	= 84·2
				1·0
				·2
				·2

°	°	h.	m.	°
Lat. 39	Decl. 22	H.A. 4	32	= 85·2
39	22	4	40	= 84·0
				1·2
				6
				8) 7·2
				·9

	°
H.A. 4h. 32m. gives . .	85·2
Corr. for 36′ lat., +	·36
	85·56
Corr. for 13′ dec., −	·2
	85·36
Corr. for 6m. H.A., −	·9
	84·46

	°
True az.,	S. 84·5 W.
Obs. az.,	S. 81·0 W.
Error,	3·5 E.
Var.,	4·7 E.
Dev.,	1·2 W.

Worked Example II. (S.A.T. given).

On 2nd January, 1929, at 19h. 05m., Apparent time at ship, in latitude 45° 12′ N., longitude 21° W., the planet *Venus* bore by compass S. 80° W. Required the true azimuth and error of the compass by the Time azimuth tables, and supposing the Variation to be 24° 30′ W., required the deviation of the compass for the direction of the ship's head.

Find the G.A.T. and correct E.
Find the G.M.T. for which correct R., also the planet's R.A. and Decl.
Find the R.A.M. and hour angle. Finish as in preceding worked example.

	d.	h.	m.	s.
S.A.T.,	2	19	05	00
Long. W., +		1	24	00
G.A.T.,	2	20	29	00

	h.	m.	s.
H.A.T.S.,	7	5	0
E., −	11	55	48
S.M.T.,	2	19	09	12
Long. W., +|	1	24	00
G.M.T.,	2	20	33	12

	h.	m.	s.
S.M.T.,	19	09	12
R., +	06	47	57
R.A.M.,	1	57	9
Planet's R.A.,	21	54	28
Hour angle,	4	2	41 W.

	d.	h.	m.	s.
E.,	2	20=11	55	48·8
Corr. 29m.,		—		·6
E. corrected,			11	55	48·2

Var. 2h. = 2·3
Var. 1h. = 1·15
·5
·575

	d.	h.	h.	m.	s.
R.,	2	20=	06	47	51·3
Corr. 33m., +					5·4
R. corrected,				06	47	56·7

diff. 268s.

	d.	h.	m.	s.
R.A.,	2=	21	50	38
Corr. 20h. 33m., +			3	50
R.A. corrected,			21	54	28

	s.
12h.	134
8h. 33m.	96
6,0) 23,0	
3m. 50s.	

diff. 26′.

	d.	°	′	
Decl.,	2=	14	51·6	S.
Corr. 20h. 33m., −			22·4	
Decl. corrected,		14	29·2	S.

	′
12h.	13
8h. 33m.	9·4
	22·4

Lat. 45° . . Decl. 14°

	°		°	h.	m.	°
Lat.	45	Decl.,	14	H.A.	4	0 =	121·5
	46		14		4	0 =	121·6
							·1
							·2
						+	·02

	°		°	h.	m.	°
Lat.	45	Decl.	14	H.A.	4	0 =	121·5
	45		15		4	0 =	122·1
							·6
							·5
						+	·30

	°		°	h.	m.	°
Lat.	45	Decl.	14	H.A.	4	0 =	121·5
	45		14		4	8 =	119·9
							1·6
							3
						8)	4·8
						−	·6

	°
H.A. 4h. 0m. gives .	121·5
Corr. 12′ of lat., +	·02
	121·52
Corr. 29′ of decl., +	·3
	121·82
Corr. 3m. of H.A., −	·6
	121·22

	°
True az.,	N. 121·2 W.
Obs. az.,	N. 100·0 W.
Error,	21·2 W.
Var.,	24·5 W.
Dev.,	3·3 E.

PLANET TIME AZIMUTH.

Examples for Exercise XXX.

1. On 3rd January, 1929, in latitude 40° 12′ N., longitude 150° W., when a chronometer (corrected) indicated Mean time at Greenwich (4th January) 05h. 10m. 00s., the planet *Venus* bore S. 45° W. by compass. Required the true azimuth and error of the compass by the Time azimuth tables, and supposing the Variation to be 13° 20′ E., required the deviation of the compass for the direction of the ship's head.

2. On 7th August, 1929, in latitude 35° S., longitude 45° W., when a chronometer (corrected) indicated Mean time at Greenwich 07h. 18m. 00s., the planet *Jupiter* bore by compass N. 45° E. Required the true azimuth and error of the compass by the Time azimuth tables, and supposing the Variation to be 5° W., required also the deviation.

3. On 5th August, 1929, at 01h. 30m. Apparent time at ship, in latitude 40° S., longitude 136° E., the planet *Saturn* bore by compass S. 70° W. Required the true azimuth from the Time azimuth tables, also the error and deviation of the compass. Variation 3° E.

REDUCTION TO THE MERIDIAN (Planet).

The working of this problem is begun in exactly the same way as when doing a planet time azimuth.

Find the G.M.T. if it is not given, also the S.M.T.

Correct the planet's Right Ascension and Declination.

Correct R. also E. if appt. time is given, find the R.A.M. and the planet's hour angle.

Correct the observed altitude and find the zenith distance at the time of observation.

Calculate the "meridian zenith distance" and finish in the same way as in ex-meridian of sun or star.

Worked Example.

On 3rd January, 1929, in latitude by account °40 18′ N., longitude 147° 30′ W., the observed altitude of *Mars* near the meridian was 76° 15′ South of observer, index error 2′ 30″ to add, height of eye 28 feet; time by a chronometer (4th January) 08h. 42m. 00s., which was correct Mean time at Greenwich. Required the latitude.

	d.	h.	m.	s.
G.M.T., . .	4	08	42	00
Long. W., . .—		9	50	00
S.M.T., . .	3	22	52	00
R., . . .+		06	53	53
R.A.M., . .		05	45	53
Planet's R.A., .		05	35	34
Hour angle, . .			10	19 W.

	°	′	
Obs. alt., . .	76	15	S.
Ind. err., . .+		2·5	
	76	17·5	
Dip, . . .—		5·2	
	76	12·3	
Ref., . . .—		·2	
True alt., . .	76	12·1	
	90	00	
Zen. dist. (obs.), .	13	47·9	= *Z X* = *p*

	d.	h.	h.	m.	s.
R., . . .	4	08	=06	53	46·2
Corr. 42m., . .			+		6·9
R. corrected, . .			06	53	53·1

	d.	h.	m.	s.	
R.A., ...	4	=05	36	03	diff. 80s.
Corr. 8h. 42m., . .		—		29	*p* parts
R.A. corrected, . .		05	35	34	8h. 42m. = 29s.

	d.	°	′	
Decl., ...	4	=26	46·8	N.
Corr. 8h. 42m., . .		—	·1	
Decl. corrected, . .		26	46·7	N.
		90	00	
Polar dist., . . .		63	13·3	= *P X*

Given in spherical triangle *P Z X* the sides *P Z* (appx. co-lat.) *P X* (polar dist.), *Z X* (*p*) (the obs. zen. dist.) and angle *P* (the hour angle).

Required to find *P Z* ~ *P X* (the meridian zenith distance).

Formula.—Hav. *p*. — (hav. *P* sin *P Z* sin *P X*) = hav. (*P Z* ~ *P X*).

P = 10m. 19s.	log hav.	6·70458
P Z = 49° 42′	log sin	9·88234
P X = 63 13·3	log sin	9·95073
	log hav.	6·53765
	nat. hav.	0·00034
p = 13° 47·9′	nat. hav.	0·01443
	nat. hav.	0·01409
13° 38′		

	°	′	
Mer. zen. dist., . .	13	38·0	N.
Corr. decl., . . .	26	46·7	N.
Latitude, . . .	40	24·7	N.

Examples for Exercise XXXI.

1. On 5th August, 1929, in latitude by account 35° 30′ S., longitude 80° W., when a chronometer (corrected) indicated Mean time at Greenwich 13h. 08m. 20s., the observed altitude of *Jupiter* near the meridian was 33° 15′ North of the observer, index error 1′ 30″ to add, height of eye 29 feet. Required the latitude.

2. On 5th August, 1929, at 20h. 22m. Mean time at ship, in latitude by account 30° 30′ N., longitude 130° 30′ E., the observed altitude of *Saturn* near the meridian South of the observer was 37° 08′, index error 1′ 30″ to subtract, height of eye 27 feet. Required the latitude.

3. On 10th January, 1929, at 22h. 12m. Apparent time at ship, in latitude by account 40° S., longitude 160° E., the observed altitude of *Mars* near the meridian was 23° 20′ North of the observer, height of eye 50 feet, index error 2′ to add. Required the latitude.

ESSAYS.

Candidates for Master's certificates are required to write an essay on some technical subject connected with their work. The following ones have been given on several different occasions, and are likely to be repeated; they will give the candidate some idea of what is required. The time allowed for the essay is two hours.

Great Circle Sailing.

Great circle sailing is the art of finding the courses which a ship must steer, and the track which she must describe when sailing along the lesser arc of a great circle from one place to another, also of keeping her as nearly as practicable on that arc.

The lesser arc of the great circle contained between any two places is the shortest possible distance between them; it is, in fact, an imaginary straight line joining them together. If a vessel was steering exactly on the great circle course she would be heading directly towards her destination for the whole of the time, and would be a mile nearer to her port for every mile that she made good.

It is, however, not practicable to keep a vessel *exactly* on the great circle track, because to do so would involve a continually changing course. A vessel may, however, save considerable distance on a passage by keeping as nearly as practicable on the track of the great circle, and this is the usual procedure.

The position of a suitable number of points situated a few degrees of longitude apart along the great circle are calculated by means of right-angled spherical trigonometry. The vessel is then steered direct from point to point, and thus very nearly attains her object of sailing or steaming the shortest possible distance. The great circle course from any one place to another is calculated by means of spherical trigonometry, and may also be taken out by inspection from Blackburne's and other tables.

The advantages obtained from the use of great circle sailing as compared with Mercator's sailing are greatest in high latitudes, when there is a large difference of longitude between the points of departure and destination. The advantages are least, and the differences between the great circle and mercatorial courses are least, when the places of departure and destination are in low latitudes, also when the ship's course is near North or South in any latitude. If the ship was steering true North or South she would be *on* a great circle; the same remark applies if she was steering true East or West on the equator. The equator and all meridians are great circles.

Unless there is a definite reason for not following it, the great circle track is the proper one to use, and is the best, because it is the shortest. There are cases, however, when it is necessary or advisable to depart from it. It may pass through higher latitudes than are desirable for the ship to go to, it may pass over an island or other land, when, of course, it would be necessary to depart from it; also, it might pass through regions where a lot of ice may be expected or where head winds are prevalent. In the latter case, the distance saved might be more than counterbalanced by the extra strain put on the ship and by the loss of time and speed caused by battling against strong winds and heavy seas.

The statement that a ship when on the great circle course is always heading direct for her destination, yet continually changing her course, sounds contrary, but is nevertheless quite correct. Unlike a mercatorial course, which forms a rhumb line, the

great circle track cuts each successive meridian at a different angle, the ship is, therefore, steering a different course though actually heading in one and the same direction. (She is not altering her course when steering North or South true or when proceeding along the equator. The true course of a ship is the angle her track makes with the true meridian.)

A great circle drawn between any two places on a globe will clearly show that the above statements are correct, and will give practical proof of the truth of the foregoing remarks.

Steam vessels are able to make use of great circle sailing to a greater extent than sailing vessels, because the latter, being dependent upon the wind for their means of propulsion, when deciding what route they shall follow, have to consider the prevailing winds in the region through which the great circle would take them. A light head wind would have practically no effect on a steamer, but a sailing vessel meeting it would have to turn to windward across the track, thereby losing much time. For this reason she would probably make a better passage by giving up the idea of a great circle track, and selecting a route where she might reasonably expect more favourable winds.

A sailing vessel, for example, bound from Port Natal to Fremantle should go on the great circle, as, in addition to covering the shortest possible distance, she would probably get plenty of Westerly wind. Bound from Fremantle to Port Natal, the great circle track would still, of course, be the shortest possible distance, but it would be impracticable to follow it on account of the head winds. By coming across the Indian Ocean on a track a long way to the Northward of the great circle, she would cover more distance but would make a better passage.

Composite Great Circle Sailing.

Composite great circle sailing is the art of sailing a vessel on a composite track which is the shortest possible distance between any two places when a maximum latitude has been fixed upon, and it has been decided that the ship shall not go beyond that latitude.

Should a vessel, after considering the great circle track from one place to another, find that it would take her into too high a latitude, and, therefore, decides not to follow it, she should fix on what is to be her maximum latitude, and calculate and lay out a composite track.

This consists of the arcs of two separate great circles, and between them the arc of the parallel of latitude decided upon, which is the arc of a small circle, the three arcs together forming the composite track.

The great circle track from the point of departure to the maximum latitude is calculated, and the ship is sailed along it until she reaches the point where it touches the maximum latitude decided upon, which point is the vertex of the great circle on which she has been sailing. She then leaves the great circle, and sails along the parallel of maximum latitude until she reaches the vertex of another great circle (previously calculated), touching the maximum latitude and passing through the point of destination. She then leaves the parallel of latitude and sails along the arc of the second great circle to her destination.

Composite sailing is not a case of calculating a great circle direct from departure to destination, sailing along it until the maximum latitude is reached, then proceeding

along that parallel of latitude, and picking up and following the arc of the same great circle at its other end. The arcs of the two great circles (one at each end of the track) are not in any way connected with one another, except by the arc of the small circle between them.

A composite track could be used with advantage by a vessel bound from, say, the River Plate to Melbourne, in which case the ordinary great circle track would pass through too high a latitude.

Windward Great Circle Sailing.

Windward great circle sailing is the art of sailing a ship when beating against a head wind, so that she is kept on that tack or series of tacks by which she will make the most distance good in the direction of the great circle course from her position at any time to her destination.

If a sailing vessel meeting with a head wind was put on the tack on which she would lay nearest to her course taken from a Mercator's chart or calculated by Mercator's sailing, there are many cases in which she would be increasing her distance from her destination instead of approaching it.

The wind is only dead ahead when it is coming from a direction exactly opposite to the great circle course, which is the only course to be considered when turning to windward on a long passage. Assuming that the wind *is* dead ahead, as far as approaching her port goes, the ship will do just as well on one tack as the other, provided there is plenty of sea room, and that there is not a heavy swell coming from a different direction to the wind. Should there be a nasty cross sea, the ship would naturally do best on the tack on which she made the best weather of it.

Assuming the wind to be dead ahead and other conditions not having any effect, the ship should be put round on to the other tack as soon as the wind shifts if it causes her to " break off," for the simple reason that if she breaks off on one tack she will make a better course on the other. If the wind shifts so that she " comes up," she would be doing better, and would, therefore, be kept on the same tack.

By consistently taking advantage of any shift of wind, and always keeping the vessel on that tack on which she will lay nearest to the great circle course, she is being sailed to the best advantage under the existing adverse conditions. That is what is meant by the term " Windward great circle sailing."

Sumner's Method.

At any given instant of time the sun is vertically above some point on the earth's surface.

It then has a true altitude of 90°—that is, it is in the zenith of an observer in that position ; or, in other words, the observer is at a point on the earth's surface vertically below it.

In that case the observer's latitude will be the same as the sun's declination, and his longitude (the sun being on his meridian) the same amount E. or W. of the meridian of Greenwich that the sun is E. or W. of the meridian of Greenwich—*i.e.*, his longitude corresponds to the apparent sun's hour angle.

If, for example, with an altitude of 90°, the sun's declination was 20° N. and the

A.T.G. 21d. 14h. 0m. 0s., the ship's position would be Lat. 20° N., Long. 30° W. (the sun and the ship both being 2 hours W. of the meridian of Greenwich). Likewise, if the sun's declination was 23° S. and the A.T.G. 1d. 8h. 0m. 0s., the ship's position would be Lat. 23° S., Long. 60° E. (the sun and the ship both being 4 hours East of the meridian of Greenwich). The ship's position is thus determined without any calculation except that of correcting the altitude and turning the time into longitude. This case does not often occur to any one observer, but it is an interesting fact, and should be thoroughly understood.

Now, we will consider an ordinary case. Suppose the sun's true altitude to be 60° and his zenith distance 30°. If we plot a circle on the globe having a radius of 30° with its pole on that point of the earth or globe vertically under the sun, we know that the observer must have been in a position **somewhere** on that circle. **He could not get an altitude of 60° anywhere else.** It is, therefore, called a " circle of equal altitude " or " circle of position." That circle is not much use by itself, as we do not know **what part** of the circle the observer was on.

But if we wait until the sun has changed his bearing considerably, 90° is best, but much less will give a good result, and then get another true altitude and zenith distance, we can plot another small circle on the globe corresponding to this zenith distance. The pole of this small circle must also be vertically under the sun. We then have another circle of " equal altitude " or " circle of position." As the observer must also be on this circle—that is, he is on **both** circles—he can only be at one of their points of intersection, **which one it is** being determined by his D.R. position.

This is the principle of Sumner's method.

It should here be noted that the sun's true bearing is always at right angles to any part of the circumference of these circles of position.

No appreciable error will be caused if small portions of these circles are considered as straight lines, and laid down as such upon a Mercator's chart.

The direction in which these lines are to be laid is found by assuming two latitudes one on each side of the latitude by account, say 10 miles from it, and with the first altitude and polar distance, calculating two corresponding longitudes. A line is then drawn on the chart through these two points, and is called the " first line of position."

Then with the same two assumed latitudes and the second altitude and polar distance two more corresponding longitudes are calculated. Another line is drawn on the chart through these two positions, and is called the " second line of position."

If the ship has remained stationary between these two observations, the intersection of the two lines will indicate her position.

If she has moved in the interval, the first line of position must be moved with the parallel rules in direction and distance equal to the run. Where it cuts the second line will be the ship's position at the second observation.

As the sun's true bearing is always at right angles to the lines of position, it can easily be taken off the chart.

If it is required at the first observation it must be taken from the first line of position ; if required at the second observation it must be taken from the second line. In **all** cases it is 8 points or 90° to the Eastward if a morning observation, but 8 points or 90° to the Westward if an afternoon observation.

Sumner's method of finding a ship's position may also be worked by calculating

only one longitude for each observation, using the mean of the latitudes if two are given. The sun's true bearing at each observation may be found from the time-azimuth tables, and consequently the line of position at each observation, which is always at right angles to the sun's true bearing.

The line of position at each observation is then laid off at its proper angle, and made to pass through the mean latitude and the calculated longitude. The ship's position is found from these position lines in exactly the same way as if they had been obtained by calculating four longitudes.

Tides around the British Isles.

The main tidal undulation from the Atlantic approaches the English Channel and Ireland from a south-westerly direction, the line of the crest of the tidal wave being north-west and south-east, so that it reaches the south-west point of Ireland at almost the same time as it arrives at Ushant.

In the open ocean, where the depths are great, this tidal wave does not appear to exceed 5 feet in height from trough to crest. On reaching the shallower water off the coasts of England and Ireland the height of the undulation is greatly increased, and on meeting the coastline is still further increased, so much so that its height in places amounts to 25 feet, and in the upper part of the Bristol Channel it attains the abnormal height of 50 feet from trough to crest.

This undulation or tidal wave approaching our coast from the Atlantic has a greater height at its south-east part than elsewhere. Its height being about 10 feet off the south-west part of Ireland and 19 feet off Ushant. It preserves this peculiarity in its progress up the Irish, Bristol, and English Channels, the range of tide being invariably greater on the southern and eastern sides of the channels than on the northern and western sides.

The tidal wave, on striking the south-west point of Ireland, is split into two parts, one running northerly, causing high water successively on the west coasts of Ireland and Scotland. The other, running to the south-east, causing high water successively along the south coast of Ireland and the north coast of France. The latter is divided into three parts by the formation of the land, one passes up the English Channel, one up the Bristol Channel, and one up the Irish Channel.

That part of the tidal wave that proceeds up the Irish Channel meets the tidal wave that proceeds up the west coast of Ireland in the vicinity of Morecambe Bay in the Irish Sea. It will be seen, therefore, that the tidal wave after striking the south-west coast of Ireland is divided, and, passing round Ireland, is again united in the Irish Sea.

This description of the tidal undulation must not be confounded in any way with the set of the tidal streams ; it is included here to show clearly the **cause** of the tidal streams.

In the North Sea the tidal wave enters from the Atlantic Ocean between the coasts of Norway and the British Isles, and passes through the various channels formed by the Shetlands, the Orkneys, and the north point of Scotland. The average rate of the tidal stream from this undulation is moderate, not exceeding a knot and a half, but that part of the stream that enters from the Pentland Firth acquires great rapidity, amounting in spring tides to 8 knots.

The tidal wave proceeds southerly down the North Sea and meets the tidal

wave that proceeds up the English Channel at Dover. In this vicinity the tidal streams are, therefore, caused by two tidal waves, and are in consequence greatly affected by the wind that is blowing at the time. In the Channel and North Sea the tidal streams set towards Dover when the tide is rising there, and away from it as the water falls there. Throughout the Irish Sea the streams set towards Liverpool when the water is rising at that port, and away from Liverpool as the water falls there.

Over a considerable length of the coast between Portland and Selsea Bill a double tide is experienced, the first high water being due to the tidal wave from the westward, the second by an apparent counter undulation from the eastward, augmented by the rebound of the tides from the coast of France.

In the Solent two distinct high waters are experienced with an interval of from one to two hours between them. At Weymouth a double low water is experienced from the same causes.

Morecambe Bay, in the Irish Sea, is the grand receptacle of the tidal streams from both the northerly and southerly channels. Abreast of Arklow is situated that remarkable spot in the Irish Channel where the tide scarcely either rises or falls. Between the Isle of Man and Carlingford is a large space of still water, the water rising and falling without apparently any perceptible stream.

The Vernier.

The vernier was discovered by Nonius about the middle of the sixteenth century, and was improved by Pierre Vernier in 1631.

It consists of a graduated scale which is fitted in close connection with a fixed scale in such a way that it may be moved along the fixed scale by mechanical means. A rack and pinion actuated by a milled headed screw are generally employed for this purpose.

Its object is to obtain a more accurate reading of the scale or arc to which it is fitted than it would be possible to get without its use. To whatever instrument the vernier may be attached, it is constructed on the same principle, and for the same object.

In the case of the scale of inches on the barometer, where each mark is ·05 inch apart, the vernier is made equal in length to 9 divisions on the scale—that is, ·45 of an inch—and is divided into 10 equal parts, each part being ·045 of an inch.

When the zero on the vernier coincides with any mark on the scale, the 10th mark also does so—that is, if one end of the vernier coincides with a mark on the scale, the other end also does so. At any other time only one mark on the vernier can coincide with one on the scale, **the mark which does so indicates the reading.**

As each division on the vernier is ·045 inch, and each division on the scale is ·050 inch, the difference between a division on the scale and a division on the vernier is ·005 inch. That is, therefore, the degree of accuracy to which a barometer graduated in this way can be read.

On the millibar scale of the barometer, each division on the scale is equal to 1 millibar, and the vernier is made equal in length to 19 divisions or 19 millibars, and divided into 10 equal parts. Each division on the vernier is, therefore, one-tenth of 19 millibars, which is 1·9 millibars. The difference between one division on the scale and one on the vernier is ·9 millibar, or between two divisions on the scale

and one on the vernier is ·1 millibar. Barometers graduated in this way can, therefore, be read to the nearest ·1 of a millibar.

The vernier on the sextant is generally constructed as follows :—

A division on the arc is equal to 10′, and the vernier is made equal in length to 119 divisions or 19° 50′, and is divided into 60 equal parts. Each division on the vernier is, therefore, $\frac{1}{60}$ of 19° 50′, which is 19′ 50″. The difference between one division on the arc and one on the vernier is 9′ 50″, or between two divisions on the arc and one on the vernier is 10″. Sextants graduated in this way can, therefore, be read to the nearest 10″.

It may be noted that the degree of accuracy to which an instrument can be read depends on the length of a division on its vernier. In the case of the barometer scale graduated in inches, it is the difference between the length of a division on the scale and one on the vernier.

In the case of the barometer scale graduated to millibars, and the sextant graduated to 10′, it is the difference between the length of two divisions on the scale or arc and one on the vernier.

The reason for making the vernier on the millibar scale of the barometer equal in length to 19 divisions instead of 9, and the vernier on the arc of the sextant equal to 119 divisions instead of 59, is that the length of the vernier is thereby increased, the marks on it are made further apart, and it is easier to see which mark on the vernier coincides with one on the scale or arc.

The **principle** is the same in all cases.

Marine Surveying.

Marine surveying is the art of portraying on paper in the form of a chart or plan the physical characteristics of any bay, harbour, or other locality of which the survey is to be made.

While the position and details of permanent landmarks near the coastline form an important part of the work of marine surveying ; it more particularly deals with the bed of the sea, shoal patches, islands, rocks, and any other features there may be, together with the set of the tides, depth of water, and nature of the bottom.

The first part of the work is the selection of the site and the laying off of a suitable base line on the land, by means of which the positions of other objects may be ascertained. The base line should be situated on a level surface if possible, and its two ends marked by definite fixed objects. If no desirable objects are already in position —that is, if the existing objects are not suitable—the purpose can be served by erecting two flag poles in convenient places, the distance between them being very accurately measured. What that distance would be would depend on the area of the survey, but a length should be chosen with a view of saving labour in the future calculations which will have to be made. The true direction of this base line will also have to be found with great accuracy. The exact latitude and longitude of the marks at each end of it will have to be carefully calculated.

All the permanent landmarks which do not naturally offer a conspicuous point for observation should be marked, possibly with whitewash. The same process should also be adopted in the case of rocks and islands, a flag stuck firmly in the ground being useful on a level surface.

The high water mark should then be carefully denoted by means of a succession of flags placed along it, or by otherwise marking it, the flags being most closely spaced where the greatest curvature or irregularity occurs in the beach or shore, this being done to facilitate the correct drawing in of the coastline.

Having marked (where necessary) all the objects which are to be shown on the chart or plan, it is advisable to give each one an appropriate name, as this will greatly assist the memory during the progress of the work.

The next thing to be done is to carefully ascertain the position of all these objects so that they may be denoted on the chart or plan in their correct places. This is done by a process called "triangulation." Each end of the base line is made a station for observations, and from these stations angles are measured between the base line and the objects to be fixed, the angles being very carefully recorded. These stations are called "triangulation stations." By means of the angles which have been measured, triangles are formed, the base line forming one side of the triangle. As the position and true direction of the base line are known, also its exact length, the positions of the other objects can be easily deduced from it. Triangulation stations are also chosen in other known positions, from which angles are measured and bearings taken to find the exact position of other objects and to verify the position of objects which have been previously fixed. A new base line may be found when a new triangulation station is established.

Angles are also measured and bearings taken from the object whose position is required to be fixed.

Having obtained sets of triangles, the next performance is to calculate the length of the sides of the triangles where necessary, and lay off the exact position of the base line (or lines) on cartridge paper.

The first point chosen is then plotted off on its true bearings from both ends of the base line, its position being checked by means of the angles previously measured and recorded, also by the calculated length of the side of the triangle thus formed. The positions of other objects are then fixed by means of angles which have been measured between them and other known marks, the sides of the triangles which have been formed again providing a useful check. When all the triangles are laid off they should agree in fixing the position of each object as being in one definite place. If there are any discrepancies, an error has been made. It should be investigated and put right so that there shall be no doubt that the exact positions have been determined.

The coast line must be put in by means of plotting off the positions of the flags which were stuck in the ground along the high water mark. A line drawn through them will be a good representation of it. The nature of the shore should be carefully noted, and sketches should be made of any important or unusual features.

The set and drift of the tides, the depth of water, and the nature of the bottom form one of the most important parts of the survey, the value of the chart or plan depending greatly on their accuracy. The leadline must be carefully marked, feet being the best unit of measurement up to the first five fathoms. The whole of the soundings should be taken in feet if the water is not very deep. The soundings should be marked, as nearly as possible, in parallel straight lines, this being done by choosing or placing two fixed objects on shore and keeping the boat in line with them as the casts are taken. The exact time of each cast must also be taken so that the soundings may be reduced to chart datum when its level is decided upon. The distance between

the position of one sounding and the next one to it will depend upon the locality of the place, the depth of water, the nature of the bottom, and the scale to which the chart or plan is to be constructed. Should a shoal patch be discovered, care must be taken to fix its position very accurately. This is best done by means of horizontal angles between objects ashore, which angles must be carefully observed from the boat.

A " tide pole " should be erected in a suitable and sheltered position which is always accessible to the sea, so that it may show the correct level of the water at all times. It should be graduated to spaces of, say, 6 inches, and very clearly marked, so that the height of the water level may be read without having to closely approach the pole. This height should be recorded at regular intervals of time, and special attention paid to the times of high and low water, most particularly on the dates of the new and full moon, so that the " establishment of the port " may be decided upon.

Allowance should be made for wind, atmospheric pressure, and other influences likely to affect the height of the tide. As the height of the water level can be recorded at any time of the day by the above arrangements, it becomes a simple matter to reduce all the soundings to chart datum level. This may be the height of mean low water springs, but is sometimes made a foot or so below that level, in order to ensure that there will not at any time be less water than is marked on the chart.

The height of all objects on the land should be marked on the chart or plan in feet above the level of mean high water spring tides. These can generally be ascertained by means of the vertical angles which they subtend, allowance being made for the height of the tide. A compass should be engraved showing the variation.

In addition to the foregoing ones, the following essays have been given. Writing some of them for practice would be a good pastime.

Write an essay on your last voyage. Mention the principal winds and currents which you met with and any other phenomena which you observed.

Write an essay on " internal combustion " engines and " reciprocating " engines, and their advantages and disadvantages.

Write an essay on dangerous cargoes, and any particular methods you would adopt when dealing with them.

Write an essay on the duties of a master from the beginning to the end of a voyage.

Write an essay on the winds and currents of the North Atlantic.

Write an essay on the solar system, and the celestial sphere.

Write an essay on " quadruple expansion engines."

Write an essay on a master's duties and business when in port.

Write an essay on grain cargoes.

Write an essay on the business of a shipowner, introducing the terms used in connection with it.

Write an essay on " coastal navigation."

COAL CONSUMPTION.

The coal consumed as fuel by a steam vessel varies approximately as the cube of her speed.

For example, if a vessel consumed 20 tons a day at 10 knots, and we wished to find how much she would burn at 12 knots, we have the proportions, thus—

As 10^3 is to 12^3 so is 20 tons to **the tons per day at 12 knots.**

These proportions will only hold good when we have the consumption given at a certain speed for a definite time, per day or per hour ; we are then able to obtain the approximate consumption at a different speed for the same definite time, per day or per hour.

When distance is introduced the time is made indefinite, so that the above proportions do not give good results ; the consumption then varies as the square of the speed.

(1) **When no distance is given the consumption varies as the cube of the speed.**

(2) **When any distance is given the consumption varies as the square of the speed.**

The following worked examples will better serve to show the application of these two rules.

Worked Examples.

No. 1.

If 9 tons of coal per hour is burnt to obtain a speed of 13 knots, how much would be required to get a speed of 11 knots ?

As 13^3 is to 11^3 so is 9 tons to required quantity.

13 knots	log 1·113943	11 knots	log 1·041393
	3		3
13^3	log 3·341829	11^3	log 3·124179
		9 tons	log 0·954243
	Tons.		
	5·452		log 4·078422
	20	13^3	log 3·341829
	9·040		log 0·736593

Ans. 5 tons 9·0 cwts.

No. 2.

A steamer doing 16 knots burns 7 tons coal in 1 hour. How much would she burn to attain her full speed of 17 knots ?

As 16^3 is to 17^3 so is 7 tons to required quantity.

16 knots	log 1·204120	17 knots	log 1·230449
	3		3
16^3	log 3·612360	17^3	log 3·691347
		7 tons	log 0·845098
	Tons.		
	8·396		4·536445
	20	16^3	log 3·612360
	7·920		0·924085

Ans.—8 tons 7·9 cwts.

No. 3.

A steamer burns 7 tons of coal per hour to get a speed of 7·8 knots. What speed will she attain on a consumption of 9 tons ?

As 7 tons is to 9 tons so is $7{\cdot}8^3$ to cube of required speed.

7·8 knots	log 0·892095
	3
$7{\cdot}8^3$	log 2·676285
9 tons	log 0·954243
	log 3·630528
7 tons	log 0·845098
Cube of speed,	log 2·785430
Cube root,	log 0·928477 = 8·482 knots.

No. 4.

When consuming 17 tons coal per hour a steamer's engines make 89 revolutions per minute. How many revolutions will she make on 14 tons ?

As 17 tons is to 14 tons so is 89^3 to cube of required revolutions.

89 revs.	log 1·949390
	3
89^3	log 5·848170
14 tons	log 1·146128
	log 6·994298
17 tons	log 1·230449
Cube of revs.,	log 5·763849
Cube root,	log 1·921283 = 83·42 revolutions.

No. 5.

A steamer has sufficient coal to steam 488 miles at 16 knots. If she has to do 610 miles on the same coal, how fast must she steam ?

As 610 is to 488 so is 16^2 to S^2 (where S = speed required).

Given speed, . . .	16 knots	log 1·204120
		2
	16^2	log 2·408240
Distance for which speed is given	488	log 2·688420
		log 5·096660
Other distance, . . .	610	log 2·785330
Square of required speed (S^2)		log 2·311330
Square root (S)		log 1·155665 = 14·31 knots.

No. 6.

A steamer is 965 miles from her port of destination. She has enough coal to do 720 miles at a speed of 13 knots. At what reduced speed must she steam to reach her port?

As 965 is to 720 so is 13^2 to S^2 (where S = required speed).

Given speed, . . .	13 knots	log 1·113943
		2
	13^2	log 2·227886
Distance for which speed is given, . . .	720	log 2·857332
		log 5·085218
Other distance, . . .	965	log 2·984527
Square of required speed (S^2)		log 2·100691
Square root, (S)		log 1·050346 = 11·23 knots.

No. 7.

Steaming at her full speed of 9 knots, a steamer has covered 880 miles on a consumption of 157 tons. How far could she steam on 100 tons at 7 knots?

As 157 tons is to $(9^2 \times 880)$ so is 100 tons to $(D \times 7^2)$ (where D = required dist.)

	9 knots	log 0·954243
		2
	9^2	log 1·908486
	880	log 2·944483
	100	log 2·000000
		log 6·852969
	157	log 2·195900
	$(D \times 7^2)$	log 4·657069
7 log 0·845098		log 1·690196
2		
7^2 log 1·690196	D	log 2·966873 = 926·6 miles.

No. 8.

A steamer is making a passage of 1325 miles. She has done 710 miles at her full speed of 11 knots, using 168 tons of coal. The engineer reports only 120 tons coal left. At what reduced speed must she steam to reach her port and have 15 tons coal left in her bunkers ?

As 168 tons is to $(11^2 \times 710)$ so is 105 tons to $(S^2 \times 615)$
(where S = required speed).

11 knots	log 1·041393
	2
11^2	log $\overline{2}$·082786
710	log 2·851258
105	log 2·021189
	log $\overline{6}$·955233
168	log 2·225309
$(S^2 \times 615)$	log $\overline{4}$·729924
615	log 2·788875
S^2	log $\overline{1}$·941049
S	log 0·970525 = 9·344 knots.

Examples for Exercise XXXII.

(1) If 10 tons of coal per hour are burnt to obtain a speed of 12 knots ; how much would be required for a speed of 11 knots, weather conditions being unchanged ?

(2) A steamer going 16 knots burns 7 tons of coal per hour ; how much would she burn per hour when steaming at her full speed of 18 knots ?

(3) At a speed of 9 knots a steamer consumes 4·5 tons of coal per hour ; how much would she burn at a speed of 8 knots, wind and sea being the same ?

(4) A steamer burns 8 tons of coal per hour to get a speed of 10·5 knots. What speed would she attain on a consumption of 10 tons per hour, wind and sea being the same throughout ?

(5) When consuming 18 tons of coal per hour a steamer's engines make 89 revolutions per minute. If her consumption was reduced to 14 tons per hour, how many revolutions would be obtained ?

(6) A steamer has sufficient coal to steam 1600 miles at 9 knots. At what speed must she steam to do 2000 miles on the same coal ?

(7) A steamer is 840 miles from her port of destination. At her full speed of 11 knots her supply of coal will only take her 700 miles. At what reduced speed must she steam to reach port ?

(8) A steamer has 324 tons of coal, which will take her 1660 miles at 13 knots. At what speed must she steam to cover 1900 miles with it ?

(9) A steamer consumed 180 tons of coal to steam 900 miles at 11 knots. How much would she burn to do 800 miles at 12 knots ?

(10) A steamer is making a passage of 2200 miles. She has done 1200 miles at 12 knots, using 380 tons of coal. At what reduced speed must she steam to fetch her port if she has only 270 tons left in her bunkers ?

(11) A steamer burns 316 tons of coal to do 1500 miles at 13 knots. How far could she steam at 11 knots on 248 tons ?

(12) A vessel burns 40 tons a day at 15 knots, and has 90 tons left on board to get to port. She receives a message by wireless to proceed to another port, which is 415 miles more distant. What reduction of speed must she make ?

NOTES.

DEVIATION OF THE COMPASS.

The examination on the deviation of the compass and compass adjustment has lately (January, 1929) been a much more thorough one than it was previously, in fact it has been gradually increasing in severity for the last two or three years.

It is no use for a candidate to attempt to **learn by heart** any of the following questions and answers, thinking that he will have to write them word for word when he goes up. *Such is not the case.* An answer of his own wording is quite good enough, provided he conveys the right meaning.

He should read them over carefully, and try to get a **good general knowledge** of the subject, not attempting to commit any of them to memory.

Every one of the following questions have been given at the examinations, and among them are the latest which have been set up to the time of going to press.

They have been very carefully arranged, so that, as far as possible, one leads up to the other, making them easy to understand—and dare we say it !—interesting.

Compass adjustment and deviation form one of the important parts of the examination, and any candidate who can devote a little time to studying it while at sea will be employing that time to good advantage.

About six questions are generally given at the examination, to which written answers are required.

Describe an artificial magnet, and how a steel bar or needle is usually magnetised ; state also, how an electro magnet is made.

Ans.—An artificial magnet is a tempered steel bar that has been magnetised by artificial means, usually by means of two other magnets.

The steel bar which is to be magnetised should be laid on a flat surface, a mark being made at the middle of its length. The opposite poles of two other magnets should then be drawn simultaneously a few times from the middle to the ends of the bar, a little downward pressure being exerted. The bar should then be turned over, and be subjected to the same treatment on its other side. It will then be permanently magnetised.

An electro-magnet is made by inserting a steel bar into a spiral of insulated copper wire and passing an electric current through the wire. Looking at the bar end on, the blue pole is induced in that end at which the current circulates right-handed, the red pole, of course, being at the other end. Very powerful magnets can be made by this method, the strength depending on the length of the bar, the number of turns of the spiral round the bar, and the power of the electric current passed through it.

Which end of a magnet (or compass needle) is usually termed the red or " marked " end, and which the blue ?

Ans.—That end of the magnet which is always attracted towards the North is termed the red or " marked " end, the other end is called the blue.

What effect has the pole of one magnet of either name on the pole of the same name of another magnet, and what would be the consequence of the pole of one magnet of either name being brought near enough to affect the pole of contrary name, if in these cases both magnets were fully suspended ?

Ans.—The pole of one magnet of either name will repel the pole of the same name of any other magnet; also the pole of one magnet of either name will attract the pole of contrary name of any other magnet. In other words, poles of the same name repel, and those of contrary name attract each other.

By applying this law to all magnets, natural as well as artificial, describe what would be the result on a magnetic bar or needle, freely suspended, but by weight or by the nature of its mounting constrained to preserve a horizontal position, and what would be the result, if so mounted, but free to move in every direction, the earth being regarded as a natural magnet?

Ans.—If freely suspended but constrained to remain in a horizontal position, the result would be that the needle would point in the same direction as the magnetic meridian.

If free to move in every direction it would point to the magnetic pole. On the magnetic equator where there is no dip it would still remain in a horizontal position; but on proceeding from the magnetic equator towards the pole in either hemisphere it would take up an angle of inclination corresponding to the "dip" at that particular place.

In the Northern Hemisphere, the red end would be attracted downwards by the blue magnetic pole, and in the Southern Hemisphere the blue end would be attracted downwards by the red magnetic pole.

In stowing away compass needles or magnets, how would you place them with regard to each other, or what might be the probable consequence?

Ans.—Spare compass cards or magnets should be stowed away in such a manner that their opposite poles are together each to each respectively. If stowed with their like poles in contact, or in close proximity to each other, they would probably weaken each other, especially when subjected to such vibration as is usually experienced on board ship.

The earth being regarded as a natural magnet; which is usually termed the red and which the blue pole? Give their geographical positions.

Ans.—The South magnetic pole of the earth is termed the red pole, and the North magnetic pole the blue. The approximate position of the South magnetic pole is Lat. 73° S., Long. 155° E., the North magnetic pole being in about Lat. 70° N., Long. 97° W.

Describe the meaning of the term "vertical force" of the earth; state where it is least and where greatest. Give also an explanation of what is meant by the term "dip."

Ans.—The poles of the earth exert a magnetic force which directs the North end of the compass needle towards the North. Except on the magnetic equator and at the poles, this force has both a vertical and horizontal direction. That part which acts vertically is termed the *vertical force* of the earth. It is greatest at the magnetic poles where the whole force of the earth is vertical, and is zero on the magnetic equator where the whole force is horizontal. An observer on the magnetic equator would have the North magnetic pole bearing in a Northerly horizontal direction, but if he was at the pole it would be vertically under his feet.

On the magnetic equator a freely suspended magnetised needle would point towards the magnetic poles of the earth, maintaining a horizontal position. The red end would point towards the North pole, and the blue end towards the South pole. On receding from the magnetic equator towards the North magnetic pole, this needle (called a dipping needle) would lose its horizontal direction, and, its red end still pointing to the pole, would take up an angle of inclination which would increase as the pole was approached. On arrival at the pole, where the total force of the earth is vertical, the needle would have inclined or " dipped " to an angle of 90° from its former horizontal position. This angle of inclination, which increases from 0 at the magnetic equator to 90° at the magnetic poles, is called the **" dip."** In London it is about 67°. On receding from the magnetic equator towards the *South* pole, the same principles would apply, but the blue end of the needle would dip downwards.

A simple definition of the term " *dip* " would be " *an abbreviation for the angular depression of the pole below the horizon.*"

Describe the meaning of the term " horizontal force " of the earth ; where it is greatest and where least, and what effect it has in respect to the increase or decrease of the directive force of the compass needle.

Ans.—As explained in the preceding answer, the earth's magnetic force acts both vertically and horizontally. That part which acts horizontally is called the " horizontal force " of the earth. It is greatest on the magnetic equator, diminishing to nothing at the poles. Its effect on the compass needle is to increase its directive force as the ship approaches the magnetic equator, and to decrease its directive force as the ship recedes from the magnetic equator.

Why is a knowledge of the magnetic dip and the earth's horizontal force important in dealing with compass deviations ?

Ans.—Because the effect of magnetic induction in vertical soft iron varies with the dip (as the tangent) and a knowledge of the dip enables us to calculate the changes in the effect of vertical iron on the compass.

A knowledge of the earth's horizontal force is important, because it is that force which supplies the directive force to the compass needle, which force varies directly as the earth's horizontal force.

The deviation of the compass due to sub-permanent magnetism varies inversely as the earth's horizontal force, knowing this we are able to calculate the changes in the deviation due to changes in that force.

Does the magnetic equator coincide with the geographical equator ? If not, state clearly how it is situated.

Ans.—The magnetic equator does not coincide with the geographical equator.

It intersects the geographical equator in about longitude 14° W. and continues North of it in an Easterly direction recrossing in about Longitude 170° W. It reaches about Lat. 10° N. near Cape Guardafui, and runs nearly parallel to the geographical equator for about 50° of longitude each side of Cape Guardafui. From Long. 170° W. to 14° W. it is South of the geographical equator, reaching a maximum latitude of about 14° in Brazil. From there it makes a fair curve to the geographical equator in 14° W.

Where can the values of the magnetic dip, the earth's horizontal force, and the variation, be found?

Ans.—On charts published in the *Admiralty Manual for the Deviations of the Compass.* The variation is also accurately shown on the Admiralty variation chart, lines of equal variation being drawn for each degree. (Isogonic lines.)

What do you understand by the terms "soft iron" and "hard iron" as regards their magnetic properties?

Ans.—By "soft iron" is meant cast iron or malleable iron which becomes instantly magnetised when brought near another magnet—*i.e.*, within the magnetic field of another magnet—but has no power of retaining magnetism, and, therefore, loses its magnetism when removed from the magnetic force.

By "hard iron" is meant tempered steel which is less susceptible to magnetisation than soft iron, but, when once magnetised, permanently retains a great deal of its magnetism.

What effect would be produced on a mass of "soft iron" by the magnetism of the earth or by any other permanent magnet?

Ans.—The magnetic poles of the earth, or the poles of any other magnet, would induce magnetism of *the opposite colour to their own* into any soft iron which came within their influence. That is, a blue pole would induce red magnetism, and a red pole would induce blue.

What is meant by "transient induced magnetism"?

Ans.—Transient induced magnetism is the term given to that magnetism which soft iron receives from the influence of the earth or a permanent magnet, but which changes as its position is altered, and is almost entirely lost when removed from that influence.

Describe (*a*) what is commonly known by the term "retentive" or "retained" magnetism, and how the ship acquires it when in port and at sea; (*b*) its effect on the compass needle whilst ship's head continues in the same direction; (*c*) the immediate consequence when the direction of the ship's head is altered; and (*d*) the special precautions to be invariably observed at sea on the alteration of the ship's course.

Ans.—"Retentive" or "retained" magnetism is the term given to magnetism which is induced into the ship by the magnetic influence of the earth when she has been lying with her head in one direction, or steering on the same course for a considerable time, but which is not permanent. That part of the hull which has been nearest to the North magnetic pole of the earth will acquire *red* polarity, and that part which has been nearest the South magnetic pole will acquire *blue*. It will not last for very long, but its intensity and the period of time for which it will remain will be increased if the ship is subjected to concussions, such as blows from the sea, vibration from the engines, etc., while it is being induced.

It does not cause any deviation as long as the ship's head is kept in the same direction as it was while the "retentive" magnetism was developing, because the induced poles are then practically in line with the compass needles. When the direction of the ship's head is changed, the induced poles are thrown

out of line, and the North end of the compass needle will be attracted towards that part of the vessel which has received blue polarity.

The immediate consequence when the direction of the ship's head is altered will be to cause an attraction of the North end of the compass *needle, and consequently also the ship's head* (the ship steering by the compass) towards the direction of the former course. The greatest deviation will be found when the magnetism has been induced with the ship's head near East or West, and the course is altered to near North or South.

The first noticeable result will be that the alteration of the course by compass will have to be larger than the alteration which it is desired to make good. Azimuths must be taken at frequent intervals, and the change of deviation very carefully allowed for. These precautions must be invariably observed, because the *force, amount of change*, and *duration* of retentive magnetism are uncertain.

Which is the red and which is the blue pole of a mass of soft vertical iron, by induction, and what effect would the upper and lower ends have on the compass needle (*a*) in the Northern Hemisphere, (*b*) in the Southern Hemisphere, (*c*) on the magnetic equator ?

Ans.—In a mass of soft vertical iron the red pole is at the lower end, and the blue pole is at the upper end when in the Northern Hemisphere. In the Southern Hemisphere the positions of the poles are reversed.

(*a*) In the Northern Hemisphere the upper end being a blue pole attracts the North point of the compass needle, and repels the South. The effect of the lower end is exactly the reverse.

(*b*) In the Southern Hemisphere the upper end being a red pole attracts the South point of the compass needle, and repels the North. The effect of the lower end is exactly the reverse.

(*c*) On the equator the vertical magnetic force is zero, consequently the effect of either end is zero.

Describe what is usually termed sub-permanent * magnetism of an iron ship, and state when and how it is acquired, and which is the red and which is the blue pole, and why it is called sub-permanent magnetism ?

Ans.—Sub-permanent magnetism is that which a ship acquires when building from the inductive influence of the earth, and which is developed by the hammering and riveting during her construction. The poles lie in the direction of the line of dip, the red pole being in that part which was nearest to the North magnetic pole of the earth when building, and the blue pole in the opposite. The magentism thus acquired is not permanent like that of a magnet, as it diminishes considerably immediately after launching ; some portion of it, however, is always retained, hence it is termed sub-permanent.

* The term sub-permanent magnetism in these question is used in the original sense, as proposed by the late Sir G. B. Airy, to denote the character of the permanent magnetism of an iron ship as distinguished from the permanent magnetism of a magnetised steel bar. The terms " sub-permanent " and " permanent " throughout these questions may, therefore, be considered as synonymous.

Would you expect the greatest disturbance of the needle from the effects of sub-permanent magnetism alone to take place when ship's head is in same direction as when building, or when her head is at right angles to the direction ; and in what direction of the ship's head would you expect to find the least disturbance ?

Ans.—I should expect the greatest disturbance when the ship is heading at right angles to the direction in which she was built, because the poles of the sub-permanent magnetism would then be at right angles to the compass needle. I should expect the least deviation when the ship is heading in the same or opposite direction to that in which she was built, as the poles of the sub-permanent magnetism would then be in line with the compass needle.

What is the theory of molecular magnetism ?

Ans.—All iron or steel substances are composed of minute particles generally called molecules.

If a permanent magnet be broken into any number of pieces, each piece, however small, even if it is only a filing, becomes a perfect self-contained magnet with distinct red and blue poles.

Now, if all these small particles be again joined together, their own individual poles will disappear, and they will form a permanent magnetic mass, having only two poles as in the original magnet.

This fact supports the argument that each molecule is in itself a magnetised body, and that the actual poles of any given magnet are simply the result of the combination of all these magnetised parts. This is the theory of " molecular magnetism."

What is meant by variation of the compass ; what is it caused by ; and where can you find the variation for any given position ?

Ans.—Variation of the compass is the angle between the true and magnetic meridians at any place. It is caused by the magnetic poles of the earth not coinciding with the geographical poles. The variation for any position may be found from the Admiralty variation chart ; it is also given approximately on all other charts.

State in what parts of the globe lying in the usual tracks of navigation the variation changes very rapidly, and what special precautions should be observed when navigating these localities ; also why a " variation " chart is then very useful.

Ans.—The variation changes very rapidly on the coast of Newfoundland, the Gulf of and River St. Lawrence, the Eastern sea-board of the United States, the English Channel and its approaches, to the South-east of Madagascar, and South-west of Australia.

Special care must be used when allowing variation in these localities, and the compass course altered in accordance with its rapid change. This will be greatest when the course is at right angles to the lines of variation.

The variation chart is very useful in these localities, because the variation and its changes are so clearly shown.

Describe what is meant by the term coefficient λ (lambda), and state how its value is found.

Ans.—Coefficient λ is the ratio or proportion that the mean directive force of the compass needle on board has to the directive force of the same needle on shore, where it is free from local attraction. For convenience the directive force on shore is considered to be unity or 1·0.

It may have a certain value in one part of the ship and a different value in another part of the same ship. To find " lambda " we must find the directive force on four equidistant points of the compass, then by taking their mean we have the mean directive force of the compass needle compared with the directive force on shore.

The horizontal vibrating needle is the instrument used to find lambda, although it may just as readily be found by using the compass itself.

On shore, in a place free from local attraction, the horizontal vibrating needle or the compass needle is deflected about 40°, the time, in seconds, is then noted for about 10 complete vibrations (swings). We will assume this to be 18 seconds. The needle is then taken on board and vibrated in an exactly similar manner to that which was done on shore, and the time in seconds again noted, let this be 20 seconds.

As the vibrations on shore were quicker than those on board, we know that the directive force on shore is greater than the directive force on board. In order to find the comparison between the two we divide the shore time squared by the ship's time squared and multiply this result by the cosine of the deviation for the direction of the ship's head on which the vibrations were taken. This will give us lambda for one direction of the ship's head only. In order to find coefficient λ we must find the value of lambda with the ship's head on four equi-distant points of the compass, and take the mean of these results.

Coefficient lambda is generally less than 1, as the directive force on board is weakened by the horizontal soft iron which is usually in one continuous length underneath the compass.

State briefly (*a*) the essentials of an efficient compass and (*b*) what you would consider a good arrangement of the needles (that is, whether long or short, single or double, etc.) with a view to good compensation.

Ans.—The card should be large in diameter, and have little weight, the rigid material which is necessary to support it being arranged at its outer edge. By means of the use of aluminium, silk threads, and very light paper, the weight of a 10-inch dry card (Kelvin's) is now only about 190 grains.

The needles must be secured to the card in a direction truly parallel to the North and South line, and the card must be truly centred and graduated. Two or more pairs of needles are better than one long one. Eight needles are generally used, the longest (inside) pair being 3½ inches long. The directive force should be of moderate strength, if too strong the compass will be unsteady in a sea-way. The pivot should have a sharpened iridium point, the cap being fitted with a conical shaped sapphire highly polished and free from all blemishes. The lubber line should be vertical, and, together with the pivot, exactly in the fore-and-aft line of the vessel. The bowl should swing freely in its gimbals, and should be made of pure copper.

Describe how you could find the value of the variation when no charts or tables are available.

Ans.—It could be found by placing a compass on shore in a position free from local attraction, where, having no deviation, it would point magnetic, and any bearing taken by it would be a magnetic bearing.

Suppose, *at apparent noon*, it showed the magnetic bearing of the sun to be S. 15° W. The true bearing would be South. The difference between the true and magnetic bearings would be the value of the variation at that place—*i.e.*—

Sun's true bearing, ...	S. 0°
Sun's magnetic bearing, ...	S. 15° W.
Variation, ...	15° W.

It could be done on board by taking compass bearings of a suitably chosen fixed object with the ship's head steady on eight equi-distant points. The mean of these bearings would be its magnetic bearing; say they came to S. 42° W. Its true bearing could be found by observing the horizontal sextant angle between it and the sun *at apparent noon*. Again, the difference between the true and magnetic bearings would be the variation for that position.

True bearing of sun, ...	S. 0°
Angle between sun and object, say, . .	30 (object to the right)
True bearing of object, ...	S. 30° W.
Magnetic bearing of object, ...	S. 42 W.
Variation, ...	12° W.

The *deviation* of the compass being known, it could also be found by separating the deviation from the error; as under—

In this example we will assume that the observer is South of the sun, and that the known deviation is 7° W.

True bearing of sun at apparent noon, . .	N. 0°
Compass bearing of sun at same time, . .	N. 20 E.
Error of compass, ...	20° W.
Known deviation, ...	7 W.
Variation, ...	13° W.

The degree of accuracy in this case would depend on the accuracy of the deviation used.

All the preceding methods would also hold good by using the bearing of *any* celestial object *at the time when it was on the meridian*, the actual time being calculated by means of the *Nautical Almanac*.

The above methods could be used at other times, if Azimuth or other tables were available.

State briefly the chief points to be considered when selecting a position for your compass on board ship, and what should be particularly guarded against.

Ans.—A position should be selected convenient for constant observation in the middle line of the ship, and as far as possible from any large mass of iron. It must be at least 5 feet from iron deck-beams, and 12 feet from any vertical iron. Where the electric light is used it should be 40 or 50 feet from the dynamo.

The vicinity of vertical iron, and any iron subject to change of position, such as davits or ventilator cowls, should be particularly guarded against. Its position should admit of bearings being taken in any direction, and if possible it should be placed where lambda is greatest.

What is meant by the term "local attraction"? under what circumstances have ship's compasses, from recent careful investigation, been found to be affected by it, and name some of the localities in different parts of the world where this disturbance is to be found, and consequently where increased vigilance is necessary?

Ans.—Any disturbance of the compass by magnetic forces **outside** the ship is termed "local attraction." This may be caused by iron sheds, cranes, or other ships being situated near that particular ship whose compasses are being considered.

It more specially refers to the magnetic influence of the earth, and is generally most noticeable in comparatively shallow water, even though the ship may be a considerable distance from the land.

The following localities are mentioned in the *Admiralty Manual* where this disturbance is to be found :—The approaches to Cossack (North Australia) ; Cape St. Francis, Labrador ; New Ireland and Bougain ville, Solomon Islands ; Tumbora Volcano, Sumbawa Island, near Java ; Iceland and its adjacent waters, St. Helena, Ascension, the coasts of Madagascar, especially near St. Mary's Island ; Odessa Bay and the shoal South of it ; Isle de Los, West Coast of Africa, and New Zealand.

What do you mean by deviation of the compass, and how is it caused ?

Ans.—Deviation of the compass is the deflection of the compass needle from the magnetic meridian. It is caused by the magnetism of the iron, either in the ship's construction, or in her as cargo.

Describe how you would determine the deviation of your compass ; (1) by reciprocal bearings ; (2) by figures on the dock walls ; (3) by bearings of a distant object ; (4) by bearings of the sun or other celestial body.

Ans.—(1) **By Reciprocal Bearings.**—Station one observer on shore with a second compass, in a suitable place, free from local attraction, and plainly visible from the compass on board. Then with the ship's head steady on each point, the observer at each compass takes the bearing of the other at the same instant, known by a pre-arranged signal. The difference between the bearing observed by the compass on board, and the reverse of that observed by the compass on shore whilst the ship's head was at any point, will be the deviation for that point. To ensure accuracy the time may be noted at each observation by watches compared before and after.

(2) **By Figures on Dock Walls.**—Observe the compass bearing of the mark on the wall and the object when in a line; * the difference between this and the reading on the wall will be the error for the direction of the ship's head when the bearing was taken; by applying the variation, the deviation is determined.

(3) **By Bearings of a Distant Object.**—Select some well defined object, distant at least five or six miles, and find its magnetic bearing, either from the chart or from equi-distant compass bearings. The difference between the magnetic bearing and the bearing by compass with the ship's head on any point will be the deviation for that point.

(4) **By the Bearing of the Sun or other Celestial Body.**—Bring the ship's head steady on the point for which the deviation is required, and take the bearing of the celestial object, noting the exact time. The true bearing of the object must then be computed, or found from the Time Azimuth tables. The difference between the true bearing and the compass bearing will be the error of the compass. The variation can then be taken from the chart, and applying it to the error, adding or subtracting according to its sign, the deviation can be found.

Having determined the deviation with the ship's head on the various points of the compass, how do you know when it is Easterly and when Westerly?

Ans.—The deviation is Easterly when the correct magnetic bearing is to the right of the compass bearing; when it is to the left the deviation is Westerly.

Why is it necessary in order to ascertain the deviations to bring the ship's head in more than one direction?

Ans.—Because the deviation changes as the direction of the ship's head is altered.

How would you find the deviation when sailing along the coast?

Ans.—By observing the bearing by compass of any two well-defined objects or lights when in line, whose magnetic bearing when in one is either known, or can be found from the chart. These should be *fixed* objects, not lightvessels or buoys. The difference between the two bearings will be the deviation for the direction of the ship's head when the bearing was taken.

Name some suitable terrestrial objects by which you could readily obtain the deviation of the compass.

Ans.—The Wolf and Longships lights in one, also the South Stack and Skerries. Leading lights at Dovercourt, North Shields, and Blyth. Lighthouses on the South Foreland and Lizard, the Smalls and South Bishop in one, and many others.

For accuracy, what is the least number of points to which the ship's head should be brought for constructing a curve or table of deviations?

Ans.—Eight, if observed on or near the cardinal and quadrantal points.

* The figures on dock walls give the true bearing when they are seen in line with some conspicuous object behind. For example, the figures on the outside of the dock walls in Liverpool observed from the river give their true bearing when in line with the Vauxhall chimney.

Supposing you have no means of ascertaining the magnetic bearing of the distant object when swinging your ship for deviations, how could you find it approximately from equi-distant compass bearings, and how far, as a rule, should the object be from the ship when swinging or steaming round ?

Ans.—It can be found approximately by swinging the ship on to, say, eight equi-distant points, preferably the cardinal and quadrantal ones, and taking the mean of the compass bearings on these points. Care should be taken that the ship is upright, and that she is steadied for a reasonable time on each point with a view of eliminating any possible deviation due to retentive magnetism.

The objects should be a sufficient distance from the ship to ensure that the bearing is not appreciably altered by the diameter of the circle in which the ship is being swung.

Describe in detail how you would determine the deviation of your compass by bearings of the sun ; also by a star or planet.

Ans.—Take a compass bearing of the sun at a certain definite time. Calculate or take from the Azimuth Tables the *true* bearing of the sun at that time. The difference between the true and compass bearings is the error of the compass. If the true is to the right of the compass bearing the error is E., if to the left it is W. The deviation is determined by applying the variation to the error, adding if different names, but subtracting if same names. If the error is subtracted from the variation, the deviation has the opposite name to the error, in all other cases it has the same name.

The deviation is determined in the same way by means of a star or planet, remembering that the hour angle is taken from the *right* hand or P.M. side of the page when using the Azimuth Tables.

By thus finding the deviation with the ship's head steady on each point, it is a simple matter to construct a complete table of deviations.

If you determine the deviation by an azimuth or an amplitude of a heavenly body, it is then combined with variation, which together is sometimes called the correction for the compass. State when the deviation is the difference between the variation and the correction, and when the sum ; and when it is of the same name as that of the correction, and when of the contrary name.

Ans.—The deviation is the difference between the variation and correction when both have the same names, it is the sum when they have different names.

The deviation is the same name as the correction in all cases except when the correction has been subtracted from the variation, in which case it is of the contrary name.

Describe the meaning of the expression coefficient A.

Ans.—Coefficient A represents a constant deviation of the same nature and amount on all points of the compass ; + A signifying Easterly, and — A Westerly deviation.

Describe the meaning of the expression coefficient B, its signs and effects.

Ans.—Coefficient B represents the semi-circular deviation due to fore-and-aft magnetic forces. It has a maximum effect when the ship's head is East or West, decreasing to zero on the North and South points by compass.

+ B represents an attraction of the North point of the needle towards the ship's head, and causes Easterly deviation with the ship's head in the Eastern semi-circle of the compass, and Westerly deviation in the Western semi-circle.

— B represents an attraction towards the ship's stern, and causes Easterly deviations with ship's head in the Western semi-circle, and Westerly deviations in the Eastern semi-circle.

As the coefficient B (capable of being corrected) usually consists of two parts, one due to the permanent magnetism of the ship, and the other to vertical induction in soft iron, how should each of the two parts, strictly speaking, be corrected when compensating the compass?

Ans.—The part due to permanent magnetism should be compensated by permanent magnets placed fore-and-aft; the part due to vertical induction should be corrected by a vertical soft iron, or Flinders bar placed in the midship line, before the compass if the vertical iron draws the N. point aft, and *vice-versa*.

If the whole of coefficient B be corrected by a permanent magnet, what is likely to ensue as the ship changes her magnetic latitude?

Ans.—Should the whole of coefficient B be corrected by a permanent magnet, then, as the ship changed her magnetic latitude, the effect of that part arising from vertical iron, which decreases in lower latitudes, would no longer be compensated by the magnet, the force of which remains constant, and in the opposite hemisphere the magnet, instead of correcting, would increase the error.

Describe the meaning of the expression coefficient C, its signs and effects.

Ans.—Coefficient C represents the semi-circular deviation due to athwartship magnetic forces. It has a maximum effect when the ship's head is North or South by compass decreasing to zero on the East and West points.

+ C represents an attraction of the North end of the needle towards the starboard side of the ship, and causes Easterly deviation with the ship's head in the Northern semi-circle, and Westerly deviation in the Southern semi-circle.

— C represents an attraction towards the port side, and causes Westerly deviation with the ship's head in the Northern semi-circle, and Easterly deviation in the Southern semi-circle.

Describe the meaning of the expression coefficient D, its signs and effects.

Ans.—Coefficient D represents the quadrantal deviation arising from horizontal induction in soft iron, and has a maximum value on the quadrantal points, decreasing to zero on the cardinal points by compass.

+ D is caused by continuous athwartship iron, or by fore-and-aft iron divided by the compass. It produces Easterly deviation in the N.E. and S.W. quadrants, and Westerly deviation in the N.W. and S.E. quadrants.

— D is caused either by athwartship iron divided by the compass or fore-and-aft iron continuous. It produces results exactly the reverse to + D.

Describe the meaning of the expression coefficient E, its signs and effects.

Ans.—Coefficient E represents the quadrantal deviation due to horizontal soft iron when unsymmetrically distributed and when it is diagonal to the fore-and aft line. It has a maximum value when the ship's head is on the cardinal points, decreasing to zero on each quadrantal point by compass.

+ E is caused by continuous iron passing under the compass from the direction of the port bow to the starboard quarter, or by iron from the direction of the starboard bow to the port quarter if divided by the compass. It produces Easterly deviation between N.E. and N.W., or between S.E. and S.W., and Westerly deviation between N.E. and S.E., or between N.W. and S.W.

— E is caused by iron lying in a direction from port bow to starboard quarter if divided by the compass, or by continuous iron from the starboard bow to port quarter. It gives results exactly the reverse to + E.

Describe quadrantal deviation, and state what coefficients represent it, also on what points of the ship's head by compass each of these coefficients gives the greatest amount of deviation, and why it is called quadrantal deviation.

Ans.—Quadrantal deviation is caused by induced magnetism in horizontal soft iron, as before mentioned.

It is represented by the coefficients + D and — D, also by + E and — E.

Coefficient D gives the greatest amount of deviation on the four quadrantal points, N.E., N.W., S.E., and S.W.

Coefficient E gives the greatest amount of deviation on the four cardinal points, N., S., E., and W.

It is called quadrantal deviation, because it changes its name as the ship's head passes through each adjacent quadrant of the compass.

On what points of the compass will each of the coefficients D and E, + and —, give Easterly and on what points Westerly deviations?

Ans.—+ D gives Easterly deviation in the N.E. and S.W. quadrants, and Westerly deviation in the N.W. and S.E. quadrants.

— D gives deviation of the opposite name in the same quadrants.

+ E gives Easterly deviation in the Northerly and Southerly quadrants, and Westerly in the Easterly and Westerly quadrants.

– E gives deviation of the opposite name in the same quadrants.

The value of coefficient B or C being given, also the magnetic direction of the ship's head while she was being built, determine how the approximate value of the other coefficient C or B may be found, assuming that these coefficients result altogether from sub-permanent magnetism.

Ans.—This may be done by means of the Traverse Table. If B is given and C is required, enter the Traverse Table with the direction of the ship's head when building as a course and coefficient B in the D. latitude column; the value of C will be found in the adjacent departure column.

If C was given and B required, look in the Traverse Table with the direction of the ship's head when building as a course, and coefficient C in the departure column; the value of B will be found in the adjacent D. latitude column.

For Example :—

Ship's head building N. 38° E. Coefficient B = 11° in D. latitude column, coefficient C is found in departure column (8·6°).

Ship's head building S. 26° E. Coefficient C = 3·5° in departure column, coefficient B is found in D. latitude column (7·2°).

The value of coefficients B and C being given, state how you could determine the approximate direction of the ship's head while she was being built.

Ans.—Turn up the Traverse Table until you find the given values of B and C adjacent to each other, B in the D. latitude column, and C in the departure column. The corresponding course will indicate the direction of the ship's head when building.

For Example :—

Given B = 11° — and C = 6·9° +, ship's head when building was N. 32° E.
Given B = 5° — and C = 6·2° —, ship's head when building was N. 51° W.
Given B = 8° + and C = 7·5 +, ship's head when building was S. 43° E.
Given B = 3·5° + and C = 6·1 —, ship's head when building was S. 60° W.

Coefficient B being caused by sub-permanent magnetism and induction in vertical soft iron, state how you could determine the approximate value of each of these two components.

Ans.—With the direction of the ship's head when building as a course, and coefficient C in the departure column, the value of B due to sub-permanent magnetism only is found in the corresponding D. latitude column. The difference between the value of B due to sub-permanent magnetism, and the total value of B must be the amount due to vertical induction.

For Example :—

Given B = 12° —, C = 3·8° —, and ship's head when building N. 28° W., it will be found from the Traverse Table that B due to sub-permanent magnetism only has a value of 7·1°.

The total value of B being	12° —
B due to sub-permanent magnetism only being . .	7·1°—
B due to vertical induction must be	4·9°—

On the magnetic equator vertical induction in soft iron having no effect on the compass, B would be caused by sub-permanent magnetism only.

Supposing the coefficient D from horizontal soft iron were allowed to remain uncompensated, would you, or would you not, expect the D to differ in name or amount on the ship changing her magnetic latitude and hemisphere? And state the reason.

Ans.—I should not expect the D to change its name or amount. The directive force of the needle depends on the earth's horizontal force, and the disturbing force causing the D depends on the same force. The directive force of the needle and the disturbing force in the iron therefore retain the same relative value; for this reason the D should always remain the same, both in name and amount.

Provided the needles of your compass are not so long and powerful, and so near, as to cause the soft iron correctors to become magnetised by induction, would coefficient D if properly compensated be likely to remain so in all latitudes, and both hemispheres? If so, state the reason why.

Ans.—The correction would remain good in all latitudes and both hemispheres.

The induction in the horizontal iron depends upon the earth's horizontal force. The induction in the soft iron correctors depends also upon the earth's horizontal force. Any change in the disturbing force is, therefore, met by a corresponding change in the correcting force. For this reason the compensation should always remain good.

Is a knowledge of the value of the various coefficients of any advantage? If so, state why.

Ans.—Yes. A knowledge of the value of the coefficients is of great advantage. By their means we are able to compensate, in a proper manner, the various disturbing forces acting on the compass. Knowing the value of each, and the nature of the magnetism which causes them, we can compensate them with correcting forces of a like nature. By doing this, we ensure, as far as possible, that the deviations will remain practically the same in all latitudes and both hemispheres.

Also, *should* any change of deviation show itself, we are better able to trace its cause, and compensate it properly.

Moreover, from a known value of the coefficients, a complete table of the total deviation can be computed for every direction of the ship's head.

Under what circumstances does the character of A and E so change as to render it desirable that these coefficients should be disregarded or modified?

Ans.—When a vessel is being swung for compass adjustment the North end of the compass needle hangs a little in the opposite direction to that in which the ship's head is moving. This produces a temporary A and E, both of which are + when the ship's head is swung to the left, and — when swung to the right. The reason for this is the sluggishness of the soft iron in completely changing its magnetism. In order to avoid complications by introducing this temporary deviation it is a good plan to keep the ship's head steady in the required direction for a sufficient time to allow the soft iron to acquire its true polarity, and the deviations to return to their proper values.

Describe the nature of the deviation represented by coefficients + A and — A, and describe the errors in the construction of the compass, and other causes, that frequently produce it.

Ans.—Coefficient A represents a constant deviation, both in name and amount, for every direction of the ship's head, Easterly deviation always being called +, and Westerly always called —.

It may be caused by defects in the construction of the compass; such as the needles not being secured truly parallel to the North and South line of the card, an error in the graduation of the card, the lubber line not being truly in the middle fore-and-aft line of the bowl, or by an error in finding the magnetic bearing of an object used when swinging the ship for adjusting. Coefficient A due to these causes is called *Apparent* A.

A *real* A is sometimes produced by horizontal induction in iron distributed in certain unsymmetrical ways about the compass.

Generally speaking, does the magnetism induced in vertical iron usually have any effect in producing the coefficient C (ship upright), or is it generally produced by sub-permanent magnetism alone? State also, your reasons for saying so.

Ans.—When the compass is in the midship line of the ship, coefficient C is generally produced by sub-permanent magnetism alone, the induction in vertical iron not causing any part of it.

The reason is, that both sides of a vessel being alike in construction, and generally in fittings, any effect produced by vertical iron on one side of the compass will be counteracted by similar vertical iron on the other side.

Should there be, however, a mass of vertical iron on *one side of the compass only*, a coefficient C would be produced.

What conditions of the iron of a ship will produce + D and what — D?

Ans.— + D is produced by horizontal induction in continuous transverse iron such as beams, or by divided fore-and-aft iron when the compass is placed between the divided parts.

— D is produced by horizontal induction in continuous fore-and-aft iron, or by divided transverse iron when the compass is placed between the divided parts.

State clearly, then, which end of horizontal iron running athwartship (such as beams, etc.), and of horizontal iron running fore-and-aft of a ship, acquires red and which blue polarity, by induction, when ship's head is at N.E., S.E., S.W., and N.W. respectively.

Ans.—All horizontal soft iron has red magnetism induced into that part of it which is nearest to the North magnetic pole at that time.

With the ship's head at N.E. fore-and-aft iron will acquire red polarity in its fore end and blue polarity in its after end.

Athwartship iron will acquire red polarity in its port end and blue in its starboard end.

With the ship's head at S.E. fore-and-aft iron will acquire blue polarity in its fore end and red polarity in its after end.

Athwartship iron will acquire red polarity in its port end and blue in its starboard end.

With ship's head at S.W. fore-and-aft iron will acquire blue polarity in its fore end and red in its after end.

Athwartship iron will acquire red polarity in its starboard end and blue in its port end.

With ship's head at N.W. fore-and-aft iron will acquire red polarity in its fore end and blue in its after end.

Athwartship iron will acquire red polarity in its starboard end and blue in its port end.

All the above holds good in *both hemispheres.*

Describe a "dumb card" or "pelorus," and its use (*a*) in compensating a compass, (*b*) in determining the deviation.

Ans.—A dumb card or "pelorus" consists of a circular metal plate graduated in the same way as a compass card and mounted on a stand so that it may revolve freely round its central pivot in a horizontal plane. It is fitted with a lubber line and clamp screw, also a sight vane with a central screw to clamp it firmly to the plate.

Its use in compensating a compass is to get the ship's head correct magnetic on any required points by means of the known magnetic bearing of some distant object, so that the deviation forming the different coefficients may be properly corrected. The distant object may be a terrestrial one such as a church steeple, chimney stack, lighthouse, etc., or a celestial one such as the sun or a star or planet.

To determine the deviation, it must be fixed in such a position that its central pivot and lubber line are parallel to the middle fore-and-aft line of the vessel.

The sight vane must be clamped on to the card at the correct magnetic bearing of a distant object, this magnetic bearing having been previously found.

The sight vane should then be turned (together with the dumb card) until it is in line with the object. The lubber line on the pelorus will then indicate the magnetic direction of the ship's head. The difference between the magnetic direction, and the direction of the ship's head by the compass, will be the deviation for that particular point on which the ship is heading *by compass at that time.*

What is the object of compensating the compass by magnets, etc., and what are the general advantages of a compensated compass over an uncompensated one?

Ans.—The object of compensating the compass is to reduce the deviations to the smallest possible amount, and to ensure the least possible change in them when the vessel alters her magnetic latitude.

The advantages are that a compensated compass will have smaller deviations than an uncompensated one, as well as having little change in them. Also, the directive force acting on the compass needle will be equalised as nearly as possible on all points, so that when the course is altered a certain amount by the compass, the **actual direction of the ship's head** is changed by the same amount. In other words, the compass card will correctly show the actual number of degrees through which the ship's head has been turned; this would not be the case with an uncompensated compass.

If the heeling error is not compensated, the North end of the compass needle will have a tendency to go to the high or low side when the vessel rolls, thereby making the compass very unsteady in a seaway. It is, therefore, an advantage to compensate it.

Before adjusting the compasses of an iron ship, what is it desirable to do with a view to eliminating, as far as possible, what may be termed the unstable part of the magnetism of the ship?

Ans.—It is desirable that the vessel should be moored in the opposite direction to that in which she was built, or may have been lying in for some time after

launching. While lying in this direction she should be subjected to considerable vibration in order to shake off the unstable part of the induced magnetism she may have acquired while building.

Assuming you were able to arrive at the proper proportions to be corrected and were then to exactly compensate the sub-permanent magnetism of the ship by means of a permanent magnet, and the induced magnetism in vertical iron by a soft iron bar, would you expect any deviation to take place in your compass as the ship changed her latitude and hemisphere? And state your reasons for saying so.

Ans.—I should not expect much alteration in the deviation as the result of changes of latitude or hemisphere, but there might be a little change in a new ship until her sub-permanent magnetism had definitely settled down. When that had happened, the permanent part of the ship's magnetism being corrected by means of a permanent magnet, there should be practically no change.

The effect of vertical iron in a ship changes with the latitude, but being corrected by vertical iron (a soft iron bar) which *also* changes with the latitude, the disturbing and correcting forces vary in the same ratio. For that reason I should expect little or no change in the deviation.

Nevertheless, minor deviations are liable to show themselves at any time on account of retentive magnetism. Considerable changes may also be caused by collision, stranding, fire, lightning, etc., also from heeling.

Supposing your compasses were allowed to remain uncompensated, explain clearly what would be the probable changes (ship upright) in the deviations produced separately by (1) the sub-permanent magnetism of the ship alone, (2) by the induced magnetism in vertical soft iron : (*a*) on reaching the magnetic equator, (*b*) in the Southern Hemisphere.

Ans.—The deviation produced by sub-permanent magnetism alone would decrease as the ship approached the magnetic equator, be least when on it, and increase with the latitude as the ship receded from the magnetic equator into the Southern Hemisphere. It would *not* change its name.

The deviation produced by induced magnetism in vertical soft iron would decrease as the ship approached the magnetic equator where it would entirely disappear. It would increase again with the latitude as the ship receded from the magnetic equator into the Southern Hemisphere, and *would* change its name.

The deviascope (illustrated herewith) is an instrument by which candidates are examined in their practical knowledge of compass deviation and adjustment. It consists of a flat board representing the deck of a ship, a compass being fitted in its middle fore-and-aft line, also a pelorus. Its object is to show clearly the causes of deviation—that is, how the compass is affected by the sub-permanent magnetism in the hull, also the transient induced magnetism in soft iron ; and the proper way of counteracting them.

The great principle of compensation is this :—**Each force which disturbs the compass must be counteracted by a force of a similar nature, placed so as to always act in the opposite direction.**

Deviation due to sub-permanent magnetism must be corrected by permanent magnets, and that due to induced magnetism in soft iron must be corrected by means of soft iron correctors. (*See* following pages.)

Describe clearly the tentative method of compass adjustment (that is, the compensation of coefficients B, C, and D, with ship upright) as generally practised by compass adjusters in ships of the Mercantile Marine.

Ans.—The order in which the adjustments should be made is as follows :—

(1) Coefficient D, by means of the soft iron correctors.

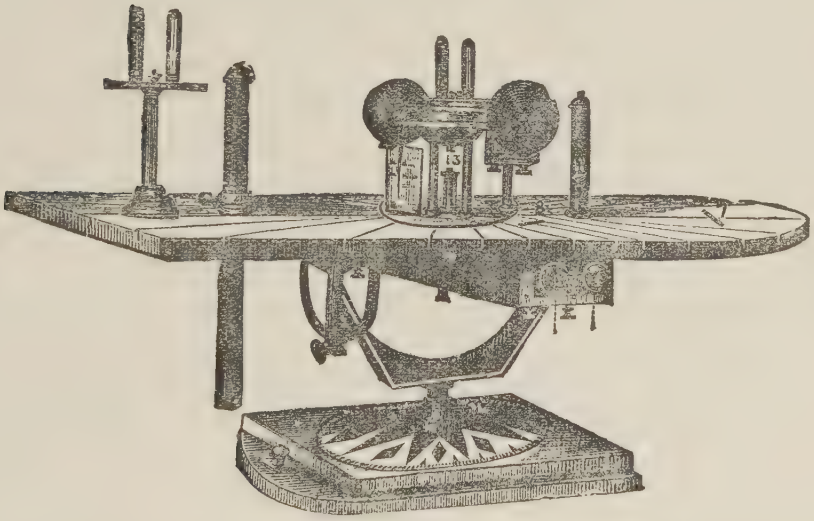
(2) The part of " B " due to vertical induction in soft iron, by means of the Flinder's bar.

(3) Heeling error, by means of a vertical magnet under the centre of the compass.

(4) Coefficient B or C, whichever is the greater, by means of a permanent magnet.

(5) Coefficient B or C, whichever is the lesser, by means of a permanent magnet.

THE DEVIASCOPE.



They are corrected in this order for the following reasons. By correcting D first we eliminate that part of the heeling error due to the vertical induction in the transverse beams, when the ship is inclined. The soft iron correctors also strengthen the directive force of the needle.

By correcting the part of B due to vertical induction in soft iron we equalise the directive force of the needle for the vertical iron before or abaft the compass.

The heeling error should be corrected before coefficients B and C, in order that no heeling error will be combined with the coefficients.

Is it necessary that the magnets used for compensating coefficent B and C should be placed on the deck ? If not, state where they may also be placed, and the rules to be observed in placing them into position.

Ans.—No. They may be secured to any convenient platform or fixture, either above or below the compass, such as a bulkhead, or the wooden pillar of the

binnacle, or top of wheelhouse, but the following conditions must be observed. The magnet for compensating coefficient B must be placed with its centre on the athwartship vertical plane which passes through the centre of the compass, and at right angles to that plane. The magnet for compensating coefficient C must be placed with its centre on the fore-and-aft vertical plane which passes through the centre of the compass, and at right angles to that plane.

State at what distance, as a general rule, the magnets and soft iron correctors should be placed from the compass needles, and what will be the consequence if they are placed too near the needles?

Ans.—The magnets should not be nearer than twice their own length from the compass needle, or their effect will be irregular and cause a fresh error, which will be greatest on the quadrantal points.

The soft iron correctors should not be nearer than $1\frac{1}{4}$ times the length of the compass needle, or they may become magnetised by induction from the needle, when their polarity would be affected as they came nearer the N. or S. points of the compass, rendering them useless as correctors. This will not occur on a modern compass having short needles.

If your correcting magnets are so mounted that their positions can be altered, describe the process by which, on open sea, you can place the ship's head correct magnetic N. (or S.), and correct magnetic E. (or W.), and can make the correction perfect.

Ans.—This is done by means of the pelorus and the magnetic bearing of the sun or other celestial body. This bearing must be calculated beforehand in readiness for the exact time of perfecting the correction.

This having been done, clamp the sight vane on the pelorus at the magnetic bearing of the object, and the required direction of the ship's head, either N., S., E., or W. to the lubber line.

When the exact time comes steer the ship very carefully, keeping the object in the sight vane. As long as the object is in the sight vane, the ship's head will be correct magnetic in the direction shown by the lubber line.

The correction can then be made perfect by moving the proper magnet until the direction of the ship's head by compass is the same as that by the pelorus.

If the ship's head is N. or S. it will be the athwartship magnet, but if E. or W. it will be the fore-and-aft one.

What effect has temperature on a permanent magnet and on soft iron?

Ans.—The effect of temperature on permanent magnets is not felt under normal atmospheric conditions, and is in fact practically unnoticeable unless the temperature is raised above 130° F. Should a magnet be heated above this temperature it will lose some of its magnetism, and will not regain it on being cooled; the final result would therefore be a weakened magnet. On being heated to a bright red heat it becomes totally non-magnetic, and remains so on being cooled.

The magnetism induced in soft iron by a magnet or by the earth's induction increases as the soft iron is heated, its maximum being reached when the iron is a dull red colour. Should it be heated to a bright red it becomes

entirely non-magnetic, and is not capable of receiving any induction. On being cooled it again acquires the power of receiving magnetism.

Assuming a vessel to be on the magnetic equator, state what deviation of your compass you would expect when your ship was heading in the same direction as that in which she was built, also in the opposite direction, and at right angles to that direction.

Ans.—The vessel being on the magnetic equator, vertical iron would not have any effect on the compass.

The deviation from sub-permanent magnetism would be least when the ship was heading in the same direction and in the opposite direction to that in which she was built. It would be greatest when heading at right angles to that direction.

Assuming the vessel to have been built with the head N.W. (mag.), she would have **red** sub-permanent magnetism on her **starboard bow**, and **blue** sub-permanent magnetism on her **port quarter.**

When heading N.W. or S.E. the poles of the sub-permanent magnetism would be in line with the compass needle, and therefore cause little or no deviation.

When heading N.E. the **red** sub-permanent magnetism on the starboard bow would **repel the red end** and **attract** the blue end of the compass needle, producing **Westerly** deviation.

When heading S.W. the **red** pole on the starboard bow would **attract the blue end** and **repel the red end** of the compass needle, producing **Easterly** deviation.

What is meant by "the composition of forces" and "the parallelogram of forces," and show how a knowledge of these is valuable in ascertaining and compensating the sub-permanent magnetism of an iron ship?

Ans.—The "composition of forces" as used in connection with compass work is simply the result obtained by finding the algebraical value of the effect of several component forces.

For instance, having determined the value of the coefficients A, B, C, D, and E, we can find the deviation caused by each one of them for any direction of the ship's head. The total algebraical value of these deviations, each of which is caused by a component force, is the result of a "composition of forces," and gives us the total deviation for that direction of the ship's head.

The "parallelogram of forces" is a parallelogram wherein two adjacent sides represent two different forces, the diagonal of the parallelogram representing the combined effect of these two forces, both in magnitude and direction.

Although we really only use half a parallelogram, a knowledge of it is valuable, as knowing the direction of the ship's head when building (provided it is not on a cardinal point) and the deviation due to sub-permanent magnetism, we can find the value of the coefficients B and C. We are thus able to separate B due to sub-permanent magnetism from the total B, and consequently to make a proper compensation for the effect of induction in vertical soft iron. Also, knowing the values of B and C due to sub-permanent magnetism, we can find the total deviation due to it, and in addition, the direction of the ship's head when building.

Describe any instrument to show the ship's heel (generally called a clinometer), and state how and where it should be fixed.

Ans.—The most common form of clinometer consists of a flat semi-circular brass plate graduated to degrees (from 0 at the bottom) on each side of a central line, and a suspended pointer which is weighted at its lower end to ensure its remaining in a vertical position.

The plate must be fixed so that when the ship is upright the central line will be vertical, and the pointer will point to 0, thus indicating the upright position. When the vessel lays over, the angle of heel will be shown by the pointer.

The clinometer should be fixed on an athwartship bulkhead, or better still, on the after side of the binnacle, where it is easily watched when taking bearings for compass deviation.

Would you expect any change to be caused in the error of your compass by the ship heeling over, either from the effect of the wind or the cargo, etc. ?

Ans.—Yes, for forces which act vertically with the ship upright, act obliquely when she heels, and therefore alter the deviation ; also the induced magnetism in the soft iron about the compass alters as the vessel heels, and therefore its effect is altered.

The compasses of iron ships being more or less affected by what is termed the heeling error, on what courses is this error usually at its minimum, and on what courses at its maximum ?

Ans.—The heeling error is usually at its minimum when the ship's head is East or West, and at its maximum when North or South by compass.

Describe clearly the three principal causes of the heeling error on board ship.

Ans.—The heeling error arises :—

(1) From transverse soft iron being moved out of a horizontal position, and thereby becoming magnetised by vertical induction ;

(2) From the induced magnetism in iron vertical to the ship's deck, becoming altered as it is moved out of the perpendicular ;

(3) From the vertical force arising from sub-permanent magnetism, which, when the vessel is upright, acts vertically on the compass and produces no deviation, but as soon as she heels it acts obliquely and causes deviation.

Under what conditions (that is, as regards position of the ship whilst building, and the arrangement of iron in the ship) is the North point of the compass needle usually drawn to windward or the high side of the ship in the Northern Hemisphere, and if not allowed for, what effect has it on the assumed position of the ship when she is steering on Northerly and on Southerly courses in the Northern Hemisphere ?

Ans.—Ships built in the Northern Hemisphere heading Northward receive blue sub-permanent magnetism in the upper after part of the vessel ; this would attract the North point of any compass placed aft to the high side of the vessel when heeling. Continuous athwartship iron, such as beams, etc., or vertical iron below the compass, would also attract the N. point to windward in the Northern Hemisphere.

The effect of this if not allowed for would be to bring the ship to windward of her assumed position when steering Northerly courses, and to leeward on Southerly courses.

Under what conditions (as in previous question) is the North point of the compass needle usually drawn to leeward or the low side of the ship in the Northern Hemisphere, and, if not allowed for, what effect would it have on the assumed position of the ship, when she is steering on Northerly and on Southerly courses in the Northern Hemisphere ?

Ans.—Ships built in the Northern Hemisphere heading near South acquire red sub-permanent magnetism in the lower and after part of the vessel ; this would repel the N. point of any compass placed aft to the low side when heeling ; also if the transverse soft iron below the compass, such as beams, does not extend right across, and the compass is placed between the ends, this would tend to increase the error caused by the sub-permanent magnetism when in North latitudes.

The effect of this would be to bring the ship to leeward of her assumed position when steering Northerly courses, and to windward on Southerly courses.

The effects being as you state, on what courses would you keep away, and on what courses would you keep closer to the wind in the Northern Hemisphere in order to make good a given compass course, (*a*) when the North point of the compass is drawn to windward or the high side of the ship ; and (*b*) when drawn to leeward or the low side of the ship ?

Ans.—(*a*) If the North point was drawn to windward I would keep away when steering Northerly courses, and closer to the wind when steering Southerly courses.

(*b*) If the North point is drawn to leeward I would keep away when steering Southerly courses, and closer to the wind when steering Northerly courses.

State clearly how that part of the heeling error due to the permanent part of the magnetism of the ship varies as the ship changes her position on the globe, and what is the reason of this ?

Ans.—The heeling error due to the sub-permanent magnetism decreases when approaching the magnetic equator, is least (but does not vanish) when on it, and increases again as the vessel goes towards higher latitudes, its effects being the same in each hemisphere.

The reason of this is that the permanent part of the ship's magnetism is of the same amount in all latitudes, and in both hemispheres, but the earth's horizontal force which directs the compass needle is less in higher latitudes, and greatest at the magnetic equator ; therefore the sub-permanent magnetism must produce a greater heeling error in higher latitudes where the directive force is less, and less error in lower latitudes where the directive force is greater.

State clearly how that part of the heeling error due to the induction in transverse iron (which was horizontal when ship was upright) and iron vertical to the ship's deck, varies as the ship changes her position on the globe.

Ans.—The heeling error caused by induced magnetism in transverse and vertical soft iron decreases when approaching the magnetic equator, is zero when on it, and increases again towards higher latitudes, producing opposite results in each hemisphere. This arises from the fact that iron in any other position than horizontal becomes magnetised by vertical induction, the upper ends receiving blue and the lower ends red magnetism when in North magnetic latitudes, and the opposite in South latitudes.

Supposing the compass were placed between the two parts of a divided beam or other athwartship iron, towards which side of the ship would iron so situated help to draw the North point of the needle when the ship heels over, (*a*) in the Northern Hemisphere, (*b*) in the Southern Hemisphere?

Ans.—In the Northern Hemisphere the North end of the needle would be drawn to the low side, and in the Southern Hemisphere it would be drawn to the high side.

What, then, would be the probable nature of the heeling error—that is, whether to the high or low side of the ship—and whether the error would be equal to the sum or difference, etc., of the forces given (1) in high North latitudes, (2) on the magnetic equator, (3) in high South latitudes? Assuming the polarity of the sub-permanent magnetism of the ship under, and affecting the compass, to be as given below; the vertical induction in soft iron, of course, obeying the ordinary laws in the above geographical positions (1), (2), (3).

Ans.—(*a*) In cases where the effect of *red* vertical sub-permanent magnetism is equal to that of the vertical inducton in the soft iron of the ship.

In high North latitudes there would be no heeling error, as it depends on the difference of the forces given. On the magnetic equator the North end of the compass needle would be repelled to the low side of the vessel by the effect of the sub-permanent magnetism only. In high South latitudes it would be repelled to the low side by the sum of the forces given.

(*b*) Where the effect of *red* vertical sub-permanent magnetism is greater than that of the vertical induction in the soft iron.

In high North latitudes the North end would be repelled towards the low side by the difference of the given forces. On the magnetic equator it would be repelled to the low side by the effect of the sub-permanent magnetism only. In high South latitudes it would be repelled to the low side by the sum of the forces given.

(*c*) Where the effect of *red* vertical sub-permanent magnetism is less than that of the vertical induction in the soft iron.

In high North latitudes the North end will be drawn to the high side by the difference of the forces. On the magnetic equator it will be repelled to the low side by the sub-permanent magnetism only. In high South latitudes it will be repelled to the low side by the sum of the forces.

(*d*) Where the effect of *blue* vertical sub-permanent magnetism is equal to that of the vertical induction in the soft iron.

In high North latitudes the North end of the compass needle will be drawn to the high side by the sum of the forces. On the magnetic equator it will be drawn to the high side by the sub-permanent magnetism only. In high South latitudes there will be no heeling error, as it depends on the difference of the forces.

(*e*) Where the effect of *blue* vertical sub-permanent magnetism is greater than that of the vertical induction in the soft iron.

In high North latitudes the North end of the compass needle will be drawn to the high side by the sum of the forces. On the magnetic equator it will be drawn to the high side by the sub-permanent magnetism only. In high South latitudes it will be drawn to the high side by the difference of the forces.

(*f*) Where the effect of *blue* vertical sub-permanent magnetism is less than that of the vertical induction in the soft iron.

In high North latitudes the North end of the compass needle would be drawn to the high side by the sum of the forces. On the magnetic equator it will be drawn to the high side by the sub-permanent magnetism only. In high South latitudes it will be repelled to the low side by the difference of the forces.

Do the soft iron correctors used for compensating the coefficient + D have any effect on the compass needle when the ship heels over, and if so, do they draw the needle towards the low or the high side of the ship, and do they counteract, or otherwise, the effect produced by the vertical induction in the soft iron (*a*) in the Northern Hemisphere, (*b*) in the Southern Hemisphere; and what is the reason of this?

Ans.—The soft iron correctors affect the compass needle when the ship heels over. They deflect the North end of the compass needle towards the low side of the ship in the Northern Hemisphere, and towards the high side in the Southern Hemisphere. They, therefore, tend to counteract the effect of the vertical induction in transverse iron in both hemispheres.

The reason is, that when the ship heels over, the *lower* part of the soft iron corrector which is on the *high* side of the compass, is nearest to the compass needle, and the *upper* part of the soft iron corrector which is on the *low* side of the compass is nearest to the compass needle. In the Northern Hemisphere the upper part of these soft iron correctors is blue, and the lower part red. The effect of both of them is, therefore, to deflect the North end of the compass needle towards the low side of the ship. In the Southern Hemisphere the upper part of these soft iron correctors is red, and the lower part blue. The effect of both of them is, therefore, to deflect the North end of the compass needle towards the high side of the ship.

If a ship is beating to windward, when she tacks, under what circumstances will the heeling error retain the same name, and under what circumstances will it take the contrary name?

Ans.—If, in tacking, the ship's head is northerly on one tack and southerly on the other, the heeling error **does not** change its name, but will be either E. or W. on both tacks. If, on both tacks, the ship's head is northerly or southerly the heeling **will change** its name.

If a ship is placed on the opposite tack by the change of wind, the ship's course being the same by compass, will the heeling error change its name?

Ans.—Yes, the heeling error will change its name, as the compass needle will be drawn to the right on one tack and to the left on the other, causing Easterly and Westerly deviations.

Can the heeling error be compensated? If so, state the means to be employed, and how the compensation may be effected.

Ans.—The heeling error can be corrected for one magnetic latitude only. A can with holes to contain several magnets is suspended under the compass at not less than 30 inches from the centre of the compass. With the ship's head N. or S. by compass the vessel is then heeled over; if the north end of the compass needle is drawn to the high side, then blue magnetism predominates under the compass, and this is corrected by placing a magnet in the can with its red pole uppermost. If this is not sufficient to repel the needle back to the lubber line, another magnet must be placed in the can until the heeling error is corrected. On no account must the magnets be brought nearer the compass than 30 inches. If, when heeling the vessel, the compass needle was repelled to the **low side**, then red magnetism predominates under the compass, and we should then place the magnets in the can with their blue poles uppermost.

It can also be compensated without heeling the ship by means of the "dipping needle." This is a magnetised steel needle balanced on a horizontal axis in such a manner that it is free to oscillate vertically but unable to turn horizontally. The dipping needle is first taken on shore to a place free from local attraction, and placed in line with the magnetic meridian with its red end pointing towards the North, where it will take up an inclined direction corresponding to the angle of dip at the place. In the Northern hemisphere the red end will be drawn downwards. A small weight is then placed on its blue end and moved along the needle until it remains balanced in a horizontal position.

By doing this we have compensated the needle for the vertical force of the earth. It is then placed in the same position as the compass on board, the compass being removed *pro tem.* The ship's head should be East or West magnetic when the dipping needle is placed in the position of the compass with its red or marked end pointing North. If the needle is repelled upwards or drawn downwards it must be due to the vertical force in the ship, as we have already compensated the needle for the earth's vertical force. This is compensated in the same way as before, by placing magnets in the can under the compass and 30 inches away from it. If the needle is drawn downwards we must put the magnets in with their red ends upwards to repel the needle back to the horizontal. If the needle is repelled upwards the magnets must be placed in the can with their blue poles uppermost to attract the needle back to the horizontal. When the needle is brought to a horizontal position we have compensated for the vertical force in the ship's magnetism acting through the centre of the compass.

The reason for having the ship's head East or West magnetic is that when in that position all fore-and-aft horizontal soft iron underneath the compass will be half-red and half-blue, and thus will have no effect on the dipping needle.

Should the clinometer be observed when the ship is swung to determine the deviation when the ship is upright? If so, state the reason why.

Ans.—Yes, it should be carefully watched when swinging the ship for deviations, as in the event of the ship *not* being upright, heeling error might be combined with the other deviations, thus rendering them unreliable. Also when compensating coefficient C, and to a lesser extent coefficient D, great care should be taken to see that there is no list. Should there be any, heeling error would be combined with the deviations, and the adjustments would be inaccurate.

Can the compensation of the heeling error be depended upon when the ship changes her latitude? If not, state the reason.

Ans.—No; for that part caused by induced magnetism is less in lower latitudes, and of reverse sign in each hemisphere, but the force of the compensating magnet remains constant, therefore the compensation would not continue perfect on a change of latitude.

If an ordinary standard compass placed higher than the iron top-sides be compensated whilst the ship is upright, what coefficient will be affected by heeling.

Ans.—Coefficient C. The heeling error gives a semi-circular deviation which is greatest with the ship's head North or South by compass. As coefficient C gives a semi-circular deviation which is also greatest on those points—that is the coefficient which must be affected by heeling.

Can semi-circular deviation be produced by any other force than the sub-permanent magnetism of the ship? If so, by what?

Ans.—Yes. **Any** magnetic force which does not change its polarity as the course is altered, and which disturbs the compass on account of being **placed on one side of it only,** produces Easterly deviation in one semi-circle and Westerly in the other, which deviation is called "semi-circular."

The top of all vertical soft iron is blue in the North Hemisphere, and red in the Southern. If such iron be situated before or abaft the compass **or on one side of it only** it will cause semi-circular deviation.

When a vessel is heeled over, a blue or red pole is induced on **one** side of the compass, thus also producing a semi-circular deviation.

Again, when a temporary pole (retentive magnetism) is induced in **either side** of the hull of a vessel, *so long as it remains there* it will produce semi-circular deviation.

Assuming, for the sake of clearness, that your steering compass is unavoidably placed very near to the head of the sternpost (and other vertical iron at the stern), thereby causing a very large — B from induced magnetism; describe briefly any method by which the approximate position for the compensating vertical iron bar (Flinders or Rundell's) could be estimated in order to reduce the error; describe also how you would proceed in order to improve, if not to perfect, its position after observations have been made on the magnetic equator.

Ans.—The approximate position for the Flinders bar can be found as follows:—

Knowing the direction of the ship's head when building (say N.W. by N.) and the value of coefficient C (say 5°), I should open the Traverse Table at the 34° page, and find coefficient C (5°) in the departure column. The corresponding D. lat. (7·5°) will be the amount of coefficient B due to sub-permanent

magnetism only. The difference between this and the total deviation showing (the ship's head being East or West) will be the amount of B due to induction in vertical soft iron. Assuming the deviation showing in this case to be 14°, and having found that B due to sub-permanent magnetism was 7·5°, the remainder (6·5°) would be the — B due to the sternpost or other vertical iron at the stern. I should, therefore, place the Flinders bar on the fore side of the compass, in such a position, in the middle fore-and-aft line of the vessel, that it would cause a + B of 6·5°. It would then be approximately in the correct position.

Another method of doing this is to first compensate coefficient D and then place the ship's head in the direction when building. The sub-permanent magnetism of the ship will not now cause any deviation, as it is in line with the compass needle. The only force, therefore, that **can** cause deviation is the vertical induction in soft iron, and this should then be compensated by placing the Flinders bar before or abaft the compass and moving it slowly from or towards the compass until the compass needle points correct magnetic.

On the magnetic equator there will not be any B from vertical induction, it will be due to sub-permanent magnetism alone, the whole of it should, therefore, be corrected by permanent magnets.

On reaching a high latitude (sub-permanent B having been properly corrected on the magnetic equator) the whole of B showing will be due to the vertical induction. By correcting it all with the Flinders bar, its previous position might be improved upon.

State if standard compasses as well as steering compasses are generally subject to this disturbance from induced magnetism in vertical iron; also whether the attraction in all cases is found to be towards the stern; and if not, state the conditions under which it might be towards the bow, and how the compensating soft iron bar should then be placed.

Ans.—A favourable position being chosen for standard compasses, they are not generally subject to disturbance from vertical iron so much as steering compasses are. The attraction also is not always towards the stern. Should the standard compass be abaft the upper part of the funnel, and near enough to be affected by it, the North end of the compass needle will be drawn forward while the ship is in the Northern Hemisphere. That being the case, the compensating bar should be placed abaft the compass.

Describe clearly how a Napier's diagram is constructed.

Ans.—A Napier's diagram should be constructed on a piece of paper of good quality about 20 inches long by 6 inches wide.

A straight line is drawn lengthwise down the middle of the paper, terminating an inch or so from each end; this is called the "mesial" line.

The top and bottom of this line is marked "North," a point in the middle being marked South. East is put in half-way down from North towards South, and West is shown half-way down from South towards North.

Graduate the line into points and degrees from North and South towards East and West. At each odd 5° a dot is put on the opposite side of the line to facilitate counting.

Through each point of the compass draw lines at an angle of 60 degrees with the vertical line. The lines drawn downwards from right to left should be plain, those drawn upwards from right to left should be dotted.

The diagram is then complete.

It may be noted that an equilateral triangle is formed by that part of the vertical line included between any two points and the plain and dotted lines intersecting those points.

Describe the uses to which the Napier's diagram can be applied, and its special advantages.

Ans.—Having determined the deviation for eight equidistant points all round the compass, they may be laid off on a Napier's diagram, when by drawing a flowing line through them all a complete curve of deviations is obtained.

The curve is particularly useful as a means of verifying any compass course you may have set. If you have used the proper deviation and applied it correctly, the course obtained from the curve will approximately agree with the one you have set; if it does not, some mistake has been made and can be rectified. This is a great advantage and safe-guard.

When doing intricate navigation where frequent alterations of course are necessary, a curve drawn for a few points on each side of possible courses is often used. It can be drawn quickly, and is just as useful as a whole curve, the greater part of which is not wanted at the time.

It can also be used for checking the correction of bearings as well as courses.

When swinging your ship, if it be required to construct deviation tables for two or more compasses situated in different parts of the vessel, describe the process, and how you would employ Napier's diagram for this purpose.

Ans.—I should have an observer stationed at each compass for which deviation tables were required.

By means of a pelorus and the correct magnetic bearing of a distant object, I should *steady the ship's head* on, say, eight equi-distant points (correct magnetic).

When the ship's head was quite steady, the observer at each compass would note the direction of the ship's head *by that compass*. The difference between that direction and the correct magnetic direction would be the deviation for the point on which the ship's head was steadied at the time.

Having thus obtained the deviation of each compass with the ship's head on eight different points correct magnetic, I should make a separate curve for each compass on a Napier's diagram.

That would be done by plotting the deviations for each of the eight points **on the plain lines**, and drawing a flowing line through them all.

Deviation tables could then be constructed for each compass by taking off the amount of deviation on each point from the **plain** lines, and putting it down on the deviation table (or card). These deviation cards would be for the **ship's head magnetic.**

By taking off the amount of deviation from the **dotted** lines, deviation cards could be made for the **ship's head by compass.**

Describe the deflector, and its uses in compass adjustment.

Ans.—The deflector in use with the deviascope consists of a strongly magnetised flat needle about $2\frac{3}{4}$ inches long, and pointed at both ends. It has a socket at the middle of its length made to take a fitting in the centre of the glass covering the compass card, being so arranged that it can be moved round horizontally and will remain steady in any required direction.

Its use in compass adjustment is to equalise the directive force of the needle on all points, so that there are no unbalanced forces remaining to cause deviation. Before commencing to adjust with the deflector, that part of B due to induction in vertical soft iron should be estimated, and corrected with a Flinders bar. It is also desirable that heeling error should be corrected beforehand, in order that it will not be combined with the other coefficients.

To correct coefficient B, bring the ship's head North by compass, and place the deflector on its fitting over the centre of the compass with its *blue* end directed towards the North point of the card, when it will be in line with the ship's head. Turn the deflector slowly round until it is at right angles to the direction of the ship's head, and carefully note the amount of deflection of the compass needle. Next, take the deflector off, and steady the ship's head on South by compass. Repeat the previous operation, and again note the deflection of the compass needle. Assume the deflections to have been 70° and 76°. The mean of these is 73°. The fore-and-aft magnets must now be placed on the athwartship line, and moved to or from the compass until it shows this mean deflection. Coefficient B will then be compensated.

To correct coefficient C, steady the ship's head on East and West by compass, put the deflector on in the athwartship position, turn it slowly round until it is truly fore-and-aft in each case, again noting the deflections. Assume these to be 74° and 80°. The athwartship magnet is now placed on the fore-and-aft line in such a position that the compass needle shows the mean of these deflections, which is 77°. Coefficient C has now been compensated.

If the mean of the deflections on East and West are greater than those on North and South, coefficient D will be + ; if they are less, it will be —. In this case we have a + D as the mean on East and West was 77°, and on North and South was 73°. With the ship's head still on West by compass, and the deflector still in the same position, the soft iron spheres are moved in or out until the compass needle shows the mean of the deflections on the four cardinal points, which is 75°. They produce a — D which corrects the + D, making the adjustment complete.

It will be noted that **no bearings have been taken** while making these compensations, one advantage of this method being that it can be used in thick weather or where no bearings are available.

Would you expect the table of deviations supplied by the compass adjuster from observations made in swinging the ship to remain good during the voyage, or would you expect the deviations to change? If so, state under what circumstances.

Ans.—I should not expect a table of deviations to remain good during the voyage, though the change would probably be less in an old ship than in a new one. The principal reason for this is that the sub-permanent magnetism in a new ship gradually decreases for some time after the vessel is launched before it eventually settles down permanently. The result of this would be that the

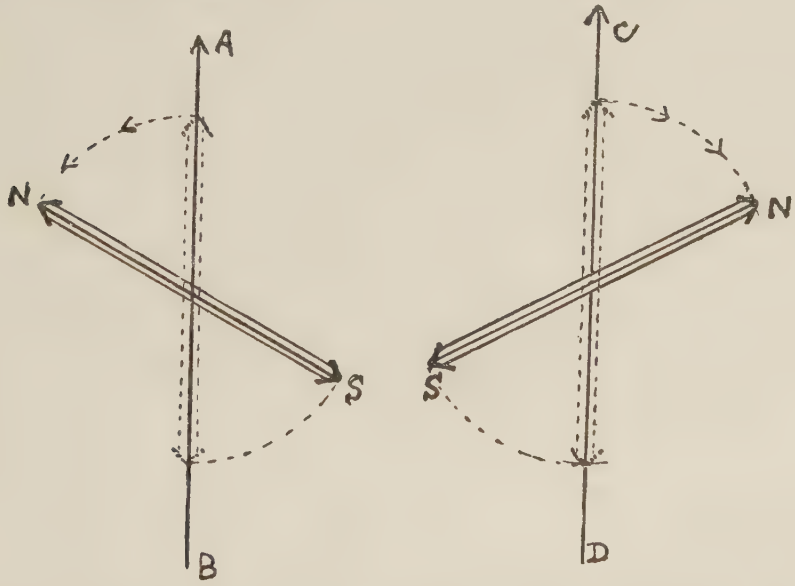
permanent compensating magnets would over-compensate the compass as the sub-permanent magnetism decreased, and after a time the compass would consequently require re-adjusting. The change of deviations from this cause would be greatest with the ship's head at right angles to the direction in which she was built. Compass adjusters also have a difficulty in exactly separating the two parts of B.

Ships employed in the coasting trade sometimes have the whole of their coefficient B compensated by permanent magnets. If such ships went into the foreign trade and changed their latitude, I should expect large changes on account of the varying effect of that part of B due to vertical induction in soft iron.

There might also be changes of deviation in any ship due to collision, stranding, fire, changes of cargo, or retentive magnetism.

Give Ampere's law for the induction of magnetism by an electric current.

Ans.—Ampere's law is as follows :—"Suppose a man swimming in the wire with the current, and that he turns so as to face the needle, then the North-seeking pole of the needle will be deflected towards the left hand."



In figure, let *A B* be the wire with a current passing through it in the direction of the arrow head, and let *N S* be a needle placed **under** the wire. A man swimming in the wire with the current in this case would have to do so face downwards to face the needle. His left hand would then be to the left-hand side of the page, and to this side the North-seeking end of the needle will be drawn, as shown in the diagram. Let *C D* be a wire with the current passing through it in the direction of the arrow head, and let *N S* be a magnetised needle **above** the wire. A man in the wire would now have to swim on his back in order to face the needle, his left hand would then be on the right-hand side of the page, and the North-seeking (red) end of the needle would then also be drawn to the right, as shown in the diagram.

THE GYRO COMPASS.

The steadily increasing number of vessels equipped with gyro compasses, and also the knowledge that questions relating to this subject are constantly being put to candidates for the Board of Trade certificates of competency, has made it essential that an elementary description of its operation should be incorporated in this edition. This new chapter is, therefore, put before candidates with a view to giving them an insight into this comparatively new subject. The author's special thanks are due to Mr. F. S. Clifford, late Second Officer in the Cunard Line, but now of the Sperry Gyroscope Company, Limited, for preparing the manuscript.

The Gyro Compass.

The fundamental principles underlying the operation of the gyro compass can be understood easily, but knowledge of the magnetic compass is of no help, for the reason that the true north compass has nothing in common with the earth's magnetism.

In order that the reader should comprehend the essential facts of this modern aid to navigation, it is necessary to differentiate between the simple gyroscope and the gyro compass.

Taking the simple gyroscope first, which is illustrated in Fig. 1, it will be seen to consist of a wheel whose axle runs in bearings contained in a ring. This gives freedom of rotation about the spinning axle, and is known as "the first degree of freedom." The ring is supported by pivots and bearings on another ring (half), which gives freedom about a horizontal axis, and is called "the second degree of freedom," while the latter (half) ring is provided with a pivot and is supported by the stand, and gives freedom about a vertical axis—"the third degree of freedom."

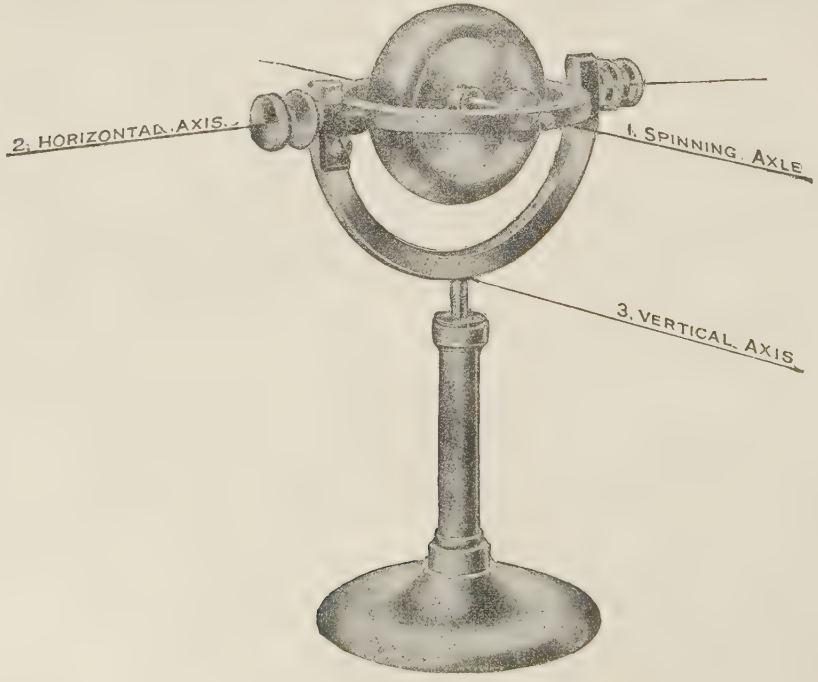


Fig. 1.

Given a wheel mounted in such a manner as to possess freedom in three different planes at right angles to each other, it will be found that it can be moved in any direction irrespective of the stand which supports it. Consequently, if every particle of friction in the bearings could be eliminated, the stand could be turned while the axle of the stationary wheel would remain pointing in the same direction. But as friction exists it has to be overcome by giving rotary motion to the wheel. Therefore, it may be said that as the wheel and its axle can be moved in any direction in space, so it follows that when the wheel is given rotary motion the stand can be moved while the axle and the wheel will maintain their original position.

This ability of the gyroscope to maintain its direction is known as "rigidity in space," and is the first characteristic of the gryoscope. We will now transfer our model to the equator and consider its behaviour with respect to the rotation of the earth.

In Fig. 2 the observer is regarded as being in space and looking at the North Pole when the part circle will represent an arc of the equator. The earth rotates,

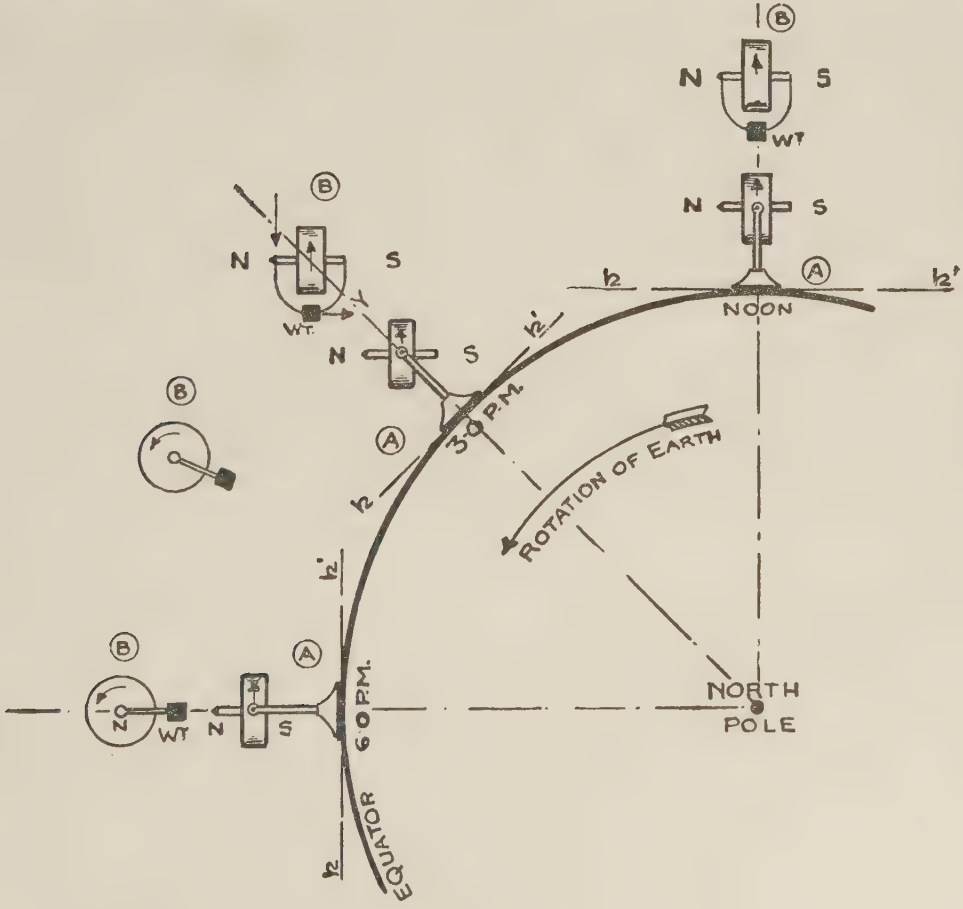


Fig. 2.

in the direction of the arrow, once in 24 hours, and the times noon, 3 P.M. and 6 P.M. are used for explanatory reasons. The figures marked B will be ignored, for the

moment. The model gyroscope (Fig. 1) is transferred to Fig. 2, and is placed on the surface of the earth at a position, called for convenience Noon (A), with its axle pointing in the direction shown, and is parallel to the earth's horizontal *h h'*. The rotation of the wheel is in the direction of the arrow.

The stand is on the earth and therefore will be carried round with it, when at 3 P.M. it will be seen that the axle has exhibited " rigidity in space," while to an observer on the earth the south end of the axle would appear to have dipped, and the north end tilted upwards to an extent equal to 45° with the earth's horizontal. Three hours later, at 6 P.M., the axle having maintained its direction in space, will now make an angle of 90° with the earth's horizontal. At midnight the " apparent " movement of the gyro axle since noon is 180°, at 6 A.M. 270°, and at the following noon it will have apparently returned to its original position. This movement is only apparent, as actually the gyro has remained fixed in space while the earth has moved under it through 360°. So true is the actual inactivity of the gyro that by a suitably arranged ring mounted on the stand, with the hours engraved thereon, it will be seen that the apparent movement of the axle would indicate the time of day.

From the foregoing it will be noted that the axle was set pointing east and west, which direction was persistent during the complete revolution of the earth. We must now consider what effect a force has on the system, as obviously under those conditions a change in direction must result, which new direction will be maintained until such time as another force is impressed upon it. Consequently, the simple model already described cannot be regarded as a compass, and, therefore, we must diagnose briefly the nature of the movement produced by a force in order to ascertain how that force can be applied so as to give to the gyroscope a definite direction.

This introduces the second characteristic of the gyroscope, which is called " Precession," and is the term used to describe the peculiar motion resulting from the application of a force to a rotating body having freedom in two or more planes.

For purposes of explanation it is convenient to refer to a man on a bicycle. If we suppose that the man was capable of balancing himself on the machine while it was stationary, then should he lean to the left—which is equivalent to a force acting on the right—the bicycle will fall to the left in the direction in which the force is acting ; or, expressed differently, there will be a movement about an imaginary horizontal axis through the plane of the machine. On the other hand, when the bicycle is being ridden and the rider leans to the left the machine would not fall, but turn to the left about an imaginary vertical axis. In other words, though a force was acting from the right so as to cause movement about a horizontal axis, the actual motion would be about the vertical axis, or at right angles to the direction of the force—which is the law of Precession.

By referring to the outside diagrams called *B* in Fig. 2 we will see how this precessional movement can be utilized to convert the gyroscope into a gyro compass. To the small gyroscope, already dealt with, we will add a small weight *W T*, which is slung from outside the spinning axle by two strips of metal in such a way that it is vertically under the wheel.

It will be seen that at the " noon " position the axle is horizontal and the weight is vertically under the gyro and towards the centre of the earth, and that an equal force is exerted on each end of the axle in such a manner that the weight has no effect on the gyro system.

Owing to the rotation of the earth, that condition can only last momentarily, since the stand supporting the gyro is carried round with the earth. The axle, in

its endeavour to maintain its direction in space, will apparently tilt, due to the rotation of the earth, with the result that the weight, acting under gravity, will resist being moved from its natural position, which is in a direction towards the centre of the earth.

The effect of gravity produced by the weight on the gyro causes a precessional movement instantly, but, in order to clearly explain its action, we will assume that the gyro has been carried round with the earth and has reached the position 3 P.M. " B."

At 3 P.M. it will be noticed that the gyro axle has maintained its direction in space, but the weight acting under gravity will want to return to a position *Y* in the plane of the dotted line shown radiating from the centre of the earth, which is the true vertical. It will be observed that this force may be represented as a downward force acting on the up-tilted end of the axle, so as to move it about its horizontal axle ; but since precession always takes place at right angles to the direction of the applied force, the gyro will turn about its vertical axis.

This turning movement will continue until the weight has reached a position in the true vertical when the effect of gravity and therefore precession, will cease.

Due to the direction of rotation of the wheel, this precessional movement about the vertical axis will be in such a way that the " N." end of the axle will turn towards the reader until it is parallel with the earth's axis and indicating a true north and south direction, as shown at the " 4.30 " and " 6 P.M." positions ; and although a temporary outside force applied to the gyro will cause a deflection from the true meridian the weight, acting under gravity, will precess it back to its only resting position. Thus, the gyro compass can be started up pointing in any direction, and will seek the geographical pole unaided.

Briefly, the gyro compass may be said to be a machine consisting of a wheel so mounted as to be free to move in three planes at right angles to each other. Its operation depends on the angular velocity of the earth's rotation about its polar axis, in order that " rigidity in space " may be exhibited, and which in turn enables the effect of gravity acting on a weight to precess the gyro axle into the true meridian. The speed of rotation of the earth is thus the essential factor in giving to the gyro compass directive force, the others being the speed of rotation of the gyro wheel and the weight of its mass, to which must be coupled the action of gravity.

NOTES.

Examination Paper I.

(1) On 14th April, 1929, at ship, being in latitude by account 10° N., longitude 21° 30′ W., required the approximate apparent time at ship when the star *α Leonis* (Regulus) would be on the meridian.

(2) Supposing you are not familiar with the stars, and wish to take an observation, find the names (from the *Nautical Almanac*) of the stars not less bright than the second magnitude that will be within one hour East and West of your meridian, above the pole and above the horizon at about 05h. 20m. apparent time at ship on 16th April, 1929, in latitude 23° 16′ N., longitude 32° 40′ W. Required also approximately the hour angle of each of the stars, and state also whether they will be to the north or south of your zenith when passing the meridian.

(3) On 16th April, 1929, the observed altitude of the star *β* Centauri on the meridian was 78° 05′ South of the observer, height of the eye 35 feet, and index error 2′ 30″ to add. Required the latitude.

(4) On 16th April, 1929, in latitude by account 48° 05′ S., and longitude 60° W., compute the approximate observed meridian altitude of *α Virginis* (Spica) as a guide to setting the sextant for observation, height of the eye 35 feet, and index error of sextant 2′ 00″ to subtract.

(5) On 20th April, 1929, in latitude by account 36° 28′ S., longitude by account 49° 30′ W., the observed altitude of the star *α Lyræ* (Vega) West of the meridian was 11° 38′, height of eye 29 feet, index error of sextant 50″ to subtract, time by a chronometer 09h. 34m. 46s., which was slow for Mean noon at Greenwich, 5th March, 1929, 01m. 58s., and losing 3·1s. daily. Required the longitude by chronometer.

(6) On 13th April, 1929, at 22h. 48m. apparent time at ship, in latitude 39° 52′ S., longitude 102° 40′ E., the star *α Bootis* (Arcturus) bore by compass N. 54° E. Required the True azimuth and error of the compass by the Time azimuth tables ; and, supposing the variation to be 18° 30′ W., required the deviation of the compass for the direction of the ship's head.

(7) On 14th April, 1929, in latitude by account 39° 04′ N., longitude 133° 40′ W., the observed altitude of the sun's L.L. near the meridian was 59° 53′ South of the observer, height of eye 27 feet, time by a chronometer 20h. 36m. 10s., which was 1m. 20s. slow of Mean time at Greenwich. Required the latitude of the ship at the time of taking the observation ; also required the latitude at noon, the ship having run 250° $3\frac{1}{2}$ miles between the time of taking the observation and noon.

(8) On 18th March, 1929, A.M. at ship, in latitude by account 50° 35′ N., longitude by account 148° E., when a chronometer (corrected) indicated Mean time at Greenwich 01h. 14m. 20s., the observed altitude of the sun's L.L. was 36° 14′, again, P.M. on the same day, when the same chronometer (corrected) indicated 05h. 36m. 16s., the observed altitude of the sun's L.L. was 22° 52·4′, height of eye 34 feet. The ship having made 47 miles on a 140° course during the interval between the observations, required the line of position when the first altitude was observed, also the sun's true bearing and position of the ship when the second altitude was observed.

(9) Two men observe the altitude of a balloon bearing in the same direction from both of them to be 32° and 45° respectively. The distance between the men being 4,500 feet, find the height of the balloon.

(10) Prove that $\sin A = \sqrt{(1 - \cos A)(1 + \cos A)}$.

ADDITIONAL FOR MASTERS.

(11) On 14th April, 1929, in longitude 24° 16′ E., when a chronometer (corrected) indicated Mean time at Greenwich 03h. 43m. 24s., the observed altitude of the Pole star out of the meridian was 33° 57′, index error 1′ 30″ to add, height of eye 28 feet. Required the latitude.

(12) On 17th June, 1929, in longitude 109° 21′ E., the observed meridian altitude of the moon's L.L. was 52° 24′ North of the observer, height of eye 21 feet. Required the latitude.

(13) When swinging the ship for deviations, the following bearings of a distant object were taken by the standard compass. Find the magnetic bearing of the object and thence the deviation on each point on which the bearings were taken.

Ship's head by compass.	Bearing of object by compass.	Deviation.	Ship's head by compass.	Bearing of object by compass.	Deviation.
North	S. 84° W.		South	N. 84° W.	
N.E.	S. 86 W.		S.W.	N. 80 W.	
East	S. 88 W.		West	N. 82 W.	
S.E.	N. 88 W.		N.W.	N. 86 W.	

Magnetic bearing required :—

Construct a curve on a Napier's diagram with the deviations as found above, and find the courses you would steer by the standard compass to make the following magnetic courses :—

Magnetic courses :— N.N.E., S. $\frac{3}{4}$ E., N.N.W., S.S.W.

Compass courses required :—

Having steered the following courses by the standard compass, find the corresponding magnetic courses from the above-named curve.

Compass courses :— E.N.E., W.N.W., W.S.W., S.W.

Magnetic courses required :—

You have taken the following compass bearings of two distant objects, the ship's head being N.W. by compass. Find the corresponding magnetic bearings.

Compass bearings :— E.S.E., S. by W.

Magnetic bearings required :—

(14) Required the first and last courses and the distance along the great circle from Port Natal in latitude 29° 53′ S., longitude 31° 3′ E., to Rottnest Island, Fremantle, in latitude 32° 0′ S., longitude 115° 31′ E. Find also, the latitude and longitude of the vertex, and the latitudes where the great circle track intersects the meridian of 35° E. and each successive 10° of longitude to destination.

Examination Paper II.

(1) On 11th May, 1929, at ship in latitude by account 26° 10′ N., longitude 84° 20′ W., required the approximate Mean time at ship when the star *a Bootis* (Arcturus) will be on the meridian.

(2) On 29th May, 1929, the observed altitude of the star *a Gruis* on the meridian was 78° 15′ South of the observer, height of eye 22 feet, index error 1′ 30″ to subtract. Required the latitude.

(3) On 20th May, 1929, in latitude by account 35° 30′ S. and longitude 30° E., compute the approximate observed meridian altitude of *a Aquilæ* (Altair) as a guide to setting the sextant for observation, height of eye 22 feet, index error of sextant 1′ 30″ to subtract.

(4) Find the names (from the *Nautical Almanac*) of the stars brighter than magnitude 2·5 that will be within $1\frac{1}{4}$ hours East and West of your meridian, above the pole and above the horizon at about 06h. 10m. Mean time at ship on 11th May, 1929, in latitude 45° 30′ S., longitude 91° 50′ E. Required also, approximately, the hour angle of each of the stars, and state also whether they will be to the North or South of your zenith when passing the meridian.

(5) On 11th May, 1929, in latitude by account 11° 38′ N., longitude by account 154° W., the observed altitude of the star *a Bootis* (Arcturus) East of the meridian was 63° 19′, height of eye 24 feet, index error 1′ 30″ to add, time by a chronometer (12th May) 07h. 24m. 01s., which was slow for Mean noon at Greenwich 12th March, 1929, 2m. 7s., and gaining 1·8s. daily. Required the longitude by chronometer.

(6) On 12th May, 1929, in latitude 41° 31′ S., longitude 16° 32′ E., when a chronometer indicated 04h. 39m. 52s. Mean time at Greenwich, the star *a Aquilæ* (Altair) bore by compass N. 2° E. Required the true azimuth and error of the compass by the Time azimuth tables, and, supposing the variation to be 31° W., required the deviation of the compass for the direction of the ship's head.

(7) On 15th May, 1929, in latitude by account 38° 51′ N., longitude 172° 46′ E., the observed altitude of the star *a Virginis* (Spica) near the meridian was 40° 14′ South of the observer, index error 1′ 00″ to subtract, height of the eye 36 feet, time by a chronometer 10h. 31m. 36s., which was 7m. 8s. slow of Mean time at Greenwich. Required the latitude.

(8) On 27th September, 1929, P.M. at ship, in latitude by account 52° 20′ N., longitude by account 5° 40′ W., when a chronometer (corrected) indicated Mean time at Greenwich 16h. 21m. 54s., the observed altitude of the sun's lower limb was 14° 54′, and again later on the same day, when the same chronometer (corrected) indicated 18h. 41m. 47s., the observed altitude of the star *Altair* was 44° 26′, height of the eye at each observation being 45 feet. The ship having made 16 miles on a 359° course during the interval between the observations, required the line of position and the latitude and longitude of the ship when the second altitude was observed, using the Marcq. St. Hilaire method by projection.

(9) A cruiser which steams 24 knots receives a message that an enemy vessel bearing N. 45° W. (true) distant 36 miles is steering S. 60° W. (true) at a speed of 18 knots. What course must the cruiser steer to intercept the enemy vessel ?

(10) The tangent of an angle is $\frac{3}{7}$, find the values of the other ratios.

Additional for Masters.

(11) On 21st May, 1929, at 04h. 46m. Mean time at ship, in longitude 65° 48′ W., the observed altitude of the star *a Ursæ Minoris* (Polaris) was 22° 43′, index error 1′ 20″ to subtract, height of eye 29 feet. Required the latitude.

(12) On 17th January, 1929, in longitude 39° 33′ W., the observed meridian altitude of the moon's upper limb was 62° 04′ South of the observer, index error 1′ 30″ to subtract, height of eye 35 feet. Required the latitude.

(13) Having taken the following compass bearings of a distant object, find its magnetic bearing and thence the deviations.

Ship's head by standard compass.	Bearing of object by standard compass.	Deviation required.	Ship's head by standard compass.	Bearing of object by standard compass.	Deviation required.
North	S. 49° E.		South	S. 22° E.	
N.E.	S. 44 E.		S.W.	S. 20 E.	
East	S. 36 E.		West	S. 26 E.	
S.E.	S. 29 E.		N.W.	S. 38 E.	

Magnetic bearing required :—

Construct a curve on a Napier's diagram with the above deviations (which you have just found) and give the courses you would steer by the standard compass to make the following magnetic courses :—

Magnetic courses :— N. 11° E., S. 50° E., S. 40° W., N. 11° W.

Compass courses required :—

Supposing you have steered the following courses by the standard compass, find the corresponding magnetic courses :—

Compass courses :— N. 34° E., S. 14° E., N. 87° W., N. 11° W.

Magnetic courses required :—

You have taken the following bearings of two distant objects by your standard compass with the ship's head at West by compass, find the corresponding magnetic bearings.

Compass bearings :— N. 34° E. East.

Magnetic bearings required :—

(14) Find the initial and final great circle courses and the distance along the great circle from Tristan-da-Cunha to Java Head. Give also, the latitude and longitude of the vertex, and the latitude where the track cuts the meridian of 10° W., and thence every tenth meridian to destination.

Tristan-da-Cunha, . . Lat. 37° 2′ S. Long. 12° 17′ W.
Java Head, . . . Lat. 6° 47′ S. Long. 105° 13′ E.

Examination Paper III.

(1) On 22nd June, 1929, at ship, in latitude by account 48° S., longitude 175° 40′ E., required the approximate apparent time at ship when the star *a Piscis Australis* (Fomalhaut) will be on the meridian.

(2) Supposing you are not familiar with the stars, and wish to take an observation, find the names (from the *Nautical Almanac*) of the stars that will be within 1h. 15m. of your meridian above the pole and above the horizon at about 04h. 58m. apparent time at ship on 25th June, 1929, in latitude 25° S., longitude 38° 40′ W. Required also approximately the hour angle of each of the stars, and state also whether they will be to the North or South of your zenith when passing the meridian.

(3) On 14th April, 1929, the observed meridian altitude of the star *β Geminorum* (Pollux) was 30° 46′ North of the observer, height of eye 25 feet, index error 2′ 0″ to subtract. Required the latitude.

(4) On 14th April, 1929, in latitude by account 31° 10′ S., longitude 98° 30′ E., compute the approximate observed meridian altitude of *a Canis Minoris* (Procyon) as a guide to setting the sextant for observation, height of eye 25 feet, index error of sextant 2′ 00″ to subtract.

(5) On 21st June, 1929, in latitude by account 54° 8′ S., longitude by account 101° W., the observed altitude of the star *a Piscis Australis* (Fomalhaut) before reaching the meridian was 38° 09′, index error 2′ 00″ to subtract, height of eye 33 feet time by a chronometer 07h. 22m. 36s., which was 2m. 28s. fast for Mean time at Greenwich. Required the longitude by chronometer.

(6) On 13th June, 1929, at 16h. 46m. 30s. apparent time at ship in latitude 46° 26′ S., longitude 43° 36′ W., the star *a Virginis* (Spica) bore by compass N. 70° E. Required the true azimuth and error of the compass by the Time azimuth tables ; and, supposing there was no variation, required the deviation of the compass for the direction of the ship's head.

(7) On 5th January, 1929, in latitude by account 36° 42′ N., longitude 42° 45′ W., the observed altitude of the sun's L.L. near the meridian was 30° 01′ South of the observer, height of eye 22 feet, time by a chronometer 15h. 26m. 08s., which was 1m. 00s. slow of Mean time at Greenwich. Required the latitude of the ship at the time of taking the observation ; also required the latitude at noon, the ship having run 022° 5 miles between noon and the time of taking the observation.

(8) On 20th April, 1929, P.M. at ship, in latitude by account 50° N., longitude by account 47° W., when a chronometer (corrected) indicated Mean time at Greenwich 16h. 46m. 11s., the observed altitude of the sun's L.L. was 46° 21′, and again P.M. on the same day when the same chronometer (corrected) indicated 20h. 25m. 23s., the observed altitude of the sun's L.L. was 14° 47′, height of the eye at each observation being 35 feet. The ship having made 36 miles on an 090° course during the interval between the observations, required the line of position and the true bearing of the sun when the first altitude was observed ; and the position of the ship when the second altitude was observed.

(9) The height of a vessel's mast from truck to waterline is 124 feet. The height of your eye being 30 feet, to what angle would you have to set your sextant to use it for maintaining a distance of one cable from her. (1 cable = 608 feet.)

(10) Prove that $(\sin A - \sec A)(\sin A + \sec A) = -\cos^2 A - \tan^2 A$.

ADDITIONAL FOR MASTERS.

(11) On 27th June, 1929, at 20h. 46m. apparent time at ship, in longitude 123° 43′ W., the observed altitude of *Polaris* out of the meridian was 18° 55′, index error 1′ 10″ to subtract, height of eye 30 feet. Required the latitude.

(12) On 19th January, 1929, in longitude 157° 32′ W., the observed meridian altitude of the moon's upper limb was 63° 34′ North of the observer, height of eye 29 feet. Required the latitude.

(13) While swinging the ship for deviations, the following compass bearings of a distant object were taken. Find its magnetic bearing and thence the deviation on each point on which the bearings were observed.

Ship's head by standard compass.	Bearing of object by standard compass.	Deviation required.	Ship's head by standard compass.	Bearing of object by standard compass.	Deviation required.
North	S. 83° W.		South	S. 70° W.	
N.E.	S. 73 W.		S.W.	S. 78 W.	
East	S. 66 W.		West	West	
S.E.	S. 62 W.		N.W.	N. 84° W.	

Required magnetic bearing :—

Construct a curve of deviations on a Napier's diagram, using the deviations as above, and give the courses you would steer by the standard compass to make the following magnetic courses :—

Magnetic courses :— N. 17° E., S. 82° E., S. 11° E., S. 87° W.

Compass courses required :—

Suppose you have steered the following courses by the standard compass, find the corresponding magnetic courses from the above-mentioned curve of deviations.

Compass courses :— N. 39° E., S. 11° E., S. 75° W., N. 20° W.

Magnetic courses required :—

You have taken the following compass bearings of two distant objects with the ship's head West by compass, find the magnetic bearings.

Compass bearings :— West. S. 11° E.

Magnetic bearings required :—

(14) Required the initial and final courses, also the distance on the great circle from Port Jackson in latitude 33° 52′ S., longitude 151° 16′ E., to Valparaiso in latitude 33° 1′ S., longitude 71° 52′ W. Find the latitude and longitude of the vertex, and the latitude of the points where the track crosses the meridian of 159° 20′ E., and thence every tenth meridian to destination.

Examination Paper IV.

(1) On 8th August, 1929, at ship, in latitude by account 20° 12′ S., longitude 23° W., required the approximate apparent time at ship when the star *a Tauri* (Aldebaran) would be on the meridian.

(2) On 20th August, 1929, the observed meridian altitude of the star β Ceti was 60° 22′ North of the observer, height of eye 28 feet, index error 1′ 20″ to add. Required the latitude.

(3) On 3rd August, 1929, in latitude by account 49° 50′ S., longitude 158° 40′ W., compute the approximate observed meridian altitude of *a Eridani* (Achernar) as a guide to setting the sextant for observation, height of eye 20 feet, index error of sextant 2′ 00″ to add.

(4) Find (from the *Nautical Almanac*) the names of the stars not less bright than the second magnitude that will be within 2 hours East and West of your meridian, above the pole and above the horizon, at about 03h. 31m. apparent time at ship on 3rd August, 1929, in latitude 49° 50′ S., longitude 158° 40′ W. Required also approximately the hour angle of each of the stars, and state also whether they will be to the North or South of your zenith when passing the meridian.

(5) On 3rd August, 1929, in latitude by account 15° 46′ S., longitude by account 76° E., the observed altitude of the star *a Lyræ* (Vega) after passing the meridian was 22° 44′, index error 1′ 30″ to subtract, height of eye 27 feet, time by a chronometer (2nd August) 19h. 38m. 46s., which was fast for Mean noon at Greenwich, 20th June, 1929, 1m. 14s., and gaining 1·7s. daily. Required the longitude by chronometer.

(6) On 3rd August, 1929, in latitude 45° 03′ N., longitude 146° 30′ W., when a chronometer (corrected) indicated 12h. 24m. 00s. Mean time at Greenwich, the star *a Tauri* (Aldebaran) bore by compass N. 77° E. Required the true azimuth and error of the compass by the Time azimuth tables, and, supposing the variation to be 20° E., required the deviation of the compass for the direction of the ship's head.

(7) On 1st August, 1929, in latitude by account 44° 05′ N., longitude 23° 46′ W., the observed altitude of the star *a Piscis Australis* (Fomalhaut) near the meridian was 15° 44′ South of the observer, index error 30″ to add, height of eye 25 feet, time by a chronometer 03h. 28m. 36s., which was 5m. 03s. fast of Mean time at Greenwich. Required the latitude.

(8) On 1st August, 1929, P.M. at ship, in latitude by account 41° N., longitude by account 45° W., when a chronometer (corrected) indicated Mean time at Greenwich 18h. 01m. 40s., the observed altitude of the sun's L.L. was 45° 50′, and again later on the same day, when the same chronometer (corrected) indicated 22h. 10m. 19s., the observed altitude of the planet *Saturn* was 22° 02′, height of the eye at each observation being 38 feet. The ship having made 36 miles on a 278° course in the interval between the observations, required the position of the ship when the second altitude was observed, using the Marcq St. Hilaire method by projection.

(9) Two ships, A and B, start simultaneously from the same meridian, A being 20 miles South of B. A steams N. 18° E. at 11 knots, B steams S. 72° E. at 10 knots. Find the distance between them when one is crossing ahead of the other.

(10) Prove that $(\operatorname{cosec} A - \cos A)(\operatorname{cosec} A + \cos A) = \cot^2 A + \sin^2 A$.

Additional for Masters.

(11) On 7th August, 1929, in longitude 125° 47′ E., when a chronometer (corrected) indicated Mean time at Greenwich (6th August) 20h. 24m. 52s., the observed altitude of the Pole star off the meridian was 27° 51′, index error 1′ to add, height of eye 28 feet. Required the latitude.

(12) On 19th January, 1929, in longitude 60° E., the observed meridian altitude of the moon's L.L. was 63° 26′ North of the observer, index error 2′ to add, height of eye 35 feet. Required the latitude.

'13) Having taken the following compass bearings of a distant object, find its magnetic bearing and thence the deviations for the direction of the ship's head at the time of taking each bearing.

Magnetic bearing required :—

Ship's head by standard compass.	Bearing of distant object by standard compass.	Deviation required.	Ship's head by standard compass.	Bearing of distant object by standard compass.	Deviation required.
North	S. 35° E.		South.	S. 13° W.	
N.E.	S. 25 E.		S.W.	S. 10 W.	
East	S. 6 E.		West	S. 22 E.	
S.E.	S. 9 W.		N.W.	S. 45 E.	

Construct a curve on a Napier's diagram with the above deviations, and give the courses you would steer by the standard compass to make the following courses magnetic.

Magnetic courses :— N. 11° E., N. 87° E., S. 11° E., N. 60° W.

Compass courses required :—

Supposing you have steered the following courses by the standard compass, find the corresponding magnetic courses.

Compass courses :— N. 34° E., S. 87° E., S. 3° W., N. 11° W.

Required magnetic courses :—

You have taken the following bearings of two distant objects by your standard compass with the ship's head at S.W. by compass, find the corresponding magnetic bearings.

Compass bearings :— N. 11° E., S. 3° E.

Required magnetic bearings :—

(14) Find the initial and final courses and the distance on the great circle from Cape Clear in latitude 51° 25′ N., longitude 9° 29′ W., to New York in latitude 40° 43′ N., longitude 74° 7′ W. Give also, the position of the vertex and the latitudes and longitudes of a succession of points 10° of longitude apart along the great circle, the first point to be in longitude 15° 25′ 55″ W.

Examination Paper V.

(1) On 24th May, 1929, the observed altitude of the star *a Coronæ Borealis* (Alphacca) on the meridian was 40° 18′ North of the observer, height of the eye 34 feet, index error 50″ to add. Required the latitude.

(2) On 24th May, 1929, in latitude by account 22° 56′ S., and longitude 154° E., compute the approximate observed meridian altitude of *a Bootis* (Arcturus) as a guide to setting the sextant for observation, height of the eye 34 feet, and index error of sextant 50″ to add.

(3) On 23rd March, 1929, in latitude by account 9° 41′ S., longitude by account 179° W., the observed altitude of the star *a Leonis* (Regulus) about 3 hours after passing the meridian was 39° 44′, index error 1′ 10″ to add, height of eye 34 feet, time by a chronometer 13h. 00m. 46s., which was fast for Mean noon at Greenwich, 12th January, 1929, 1m. 3s., and losing 1·4s. daily. Required the longitude by chronometer.

(4) On 29th December, 1929, in latitude 21° S., longitude 89° E., when a chronometer (corrected) indicated Mean time at Greenwich 17h. 23m. 40s., find the names (from the *Nautical Almanac*) of the stars brighter than magnitude 1·5 that will be within one hour East of your meridian, above the pole and above the horizon. Give the hour angle of each star, and state if they will be North or South of your zenith when crossing the meridian.

(5) On 28th December, 1929, in latitude 30° 28′ N., longitude 148° 10′ E., when a chronometer (corrected) indicated Mean time at Greenwich (27th December) 16h. 29m. 48s., the star *a Canis Majoris* (Sirius) bore by compass S. 30° W. Required the true azimuth and error of the compass by the Time azimuth tables, and assuming that there was no variation, required the deviation of the compass for the direction of the ship's head.

(6) On 20th May, 1929, in latitude by account 41° 31′ S., longitude 154° 16′ E., the observed altitude of the sun's L.L. near the meridian was 28° 16′ North of the observer, index error 1′ 10″ to add, height of eye 29 feet, time by a chronometer 02h. 02m. 18s., which was 1m. 10s. fast of Mean time at Greenwich. Required the latitude of the ship at the time of taking the observation, also required the latitude at noon, the ship having run 110° 4 miles between noon and the time of taking the observation.

(7) On 15th April, 1929, being in latitude by account 35° N., longitude 20° E., required the approximate Mean time at ship when the star *a Scorpii* (Antares) would be on the meridian.

(8) On 9th January, 1929, A.M. at ship, in latitude by account 51° 30′ N., longitude by account 31° 30′ W., when a chronometer (corrected) indicated Mean time at Greenwich 12h. 37m. 09s., the observed altitude of the sun's L.L. was 13° 25′, and again P.M. on the same day, when the same chronometer (corrected) indicated 16h. 15m. 06s., the observed altitude of the sun's L.L. was 11° 28′, height of the eye at each observation being 34 feet. The ship having made 38 miles on a 105° course during the interval between the observations, required the line of position and sun's true bearing at the first observation, also the ship's position at the second observation, using Sumner's method by projection.

(9) A and B are two ships both steaming North at 10 knots. B is 2 miles on A's starboard beam, and is ordered to increase her speed to 12 knots and take up a position 1 mile ahead of A. Find the course she will have to steer to get into that formation.

(10) Prove that $\text{cosec } 60° = \frac{2}{\sqrt{3}}$.

ADDITIONAL FOR MASTERS.

(11) On 8th August, 1929, in longitude 164° 47′ E., when a chronometer (corrected) indicated Mean time at Greenwich (7th August) 16h. 40m. 52s., the observed altitude of the Pole star out of the meridian was 31° 07′, index error 50″ to add, height of eye 35 feet. Required the latitude.

(12) On 26th April, 1929, in longitude 132° 15′ W., the observed meridian altitude of the moon's L.L. was 66° 24′ North of the observer, index error 2′ 30″ to subtract, height of eye 36 feet. Required the latitude.

(13) Having taken the following compass bearings of a distant object, find its magnetic bearing and thence the deviations on those points on which the bearings were observed.

Ship's head by standard compass.	Bearing of object by standard compass.	Deviation required.	Ship's head by standard compass.	Bearing of object by standard compass.	Deviation required.
North	West.		South	S. 65° W.	
N.E.	S. 76° W.		S.W.	S. 76 W.	
East	S. 64 W.		West	S. 86 W.	
S.E.	S. 61 W.		N.W.	West	

Magnetic bearing required :—

Construct a curve on a Napier's diagram from the above deviations, and turn the following magnetic courses into compass courses.

Magnetic courses :— N. by E., E. $\frac{1}{4}$ N., S.W. $\frac{3}{4}$ S., N.N.W.

Compass courses required :—

Turn the following compass courses into magnetic courses :—

Compass courses :— N.E., E. $\frac{3}{4}$ S., S. by W. $\frac{3}{4}$ W., N.W. $\frac{1}{4}$ W.

Magnetic courses required :—

With the ship heading W. by N. by compass, two objects bore by compass as follows ; find their magnetic bearings.

Compass bearings :— N.E., S.E $\frac{3}{4}$ E.

Magnetic bearings required :—

(14) Find the initial and final courses and the distance on the great circle from a point off Tarifa light, Straits of Gibraltar, in latitude 35° 56′ N., longitude 5° 36′ W., to a point off Cape Hatteras in latitude 35° 15′ N., longitude 75° 20′ W. Give the latitude and longitude of the vertex and the latitude of the points where the great circle crosses every tenth degree of longitude, beginning at the meridian of 10° W.

Examination Paper VI.

(1) On 26th June, 1929, the observed altitude of the star *a Ursæ Majoris* (Dubhe) below the pole was 18° 39′ bearing North, height of eye 27 feet, index error 1′ 30″ to subtract. Required the latitude.

(2) On 19th June, 1929, in latitude by account 10° S., longitude 12° W., compute the approximate observed meridian altitude of β Gruis as a guide to setting the sextant for observation, height of the eye 35 feet, and index error of sextant 1′ 30″ to add.

(3) On 20th May, 1929, in latitude by account 49° 06′ N., longitude by account 39° W., the observed altitude of the star *a Aquilæ* (Altair) before reaching the meridian was 11° 31′, index error 1′ 00″ to subtract, height of eye 27 feet, time by a chronometer (21st May) 01h. 02m. 14s., which was correct for Mean noon at Greenwich, 1st March, and gaining 1·1s. daily. Required the longitude by chronometer.

(4) On 19th June, 1929, at 04h. 08m. apparent time at ship in latitude 10° S., longitude 12° W., find the names (from the *Nautical Almanac*) of the stars of magnitude 2·5 or brighter that will be within two hours East and West of the meridian above the pole and above the horizon. Required also, approximately, the hour angle of each star, and state whether they will be to the North or South of your zenith when passing the meridian.

(5) On 27th June, 1929, at 03h. 55m. apparent time at ship, in latitude 39° 12′ S., longitude 141° 45′ W., the star *a Aquilæ* (Altair) bore by compass N. 51° W. Required the true azimuth and error of the compass by the Time azimuth tables, and supposing the variation to be 13° E., required the deviation of the compass for the direction of the ship's head.

(6) On 24th December, 1929, in latitude by account 46° 13′ S., longitude 79° W., the observed altitude of the star *a Canis Majoris* (Sirius) near the meridian was 60° 23′ North of the observer, index error 1′ 30″ to add, height of the eye 32 feet, time by a watch 05h. 42m. 32s., which had been found to be 5h. 19m. 30s. fast of apparent time at ship, but the ship had made 12′ difference of longitude to the Eastward since the determination of the error on apparent time at ship. Required the latitude.

(7) On 14th April, 1929, being in latitude by account 12° S., longitude 125° 30′ E., required the approximate apparent time at ship when the star *a Lyræ* (Vega) would be on the meridian.

(8) On 25th December, 1929, A.M. at ship, in latitude by account 50° 30′ N., longitude by account 7° 50′ W., when a chronometer (corrected) indicated Mean time at Greenwich 11h. 02m. 04s., the observed altitude of the sun's L.L. was 13° 15·4′, and again, P.M. on the same day, when the same chronometer (corrected) indicated 14h. 31m. 58s., the observed altitude of the sun's L.L. was 10° 37′, height of the eye at each observation being 30 feet. The ship having made 30 miles on an 045° course between the observations, required the ship's position at the second observation, using the Marcq St. Hilaire method by projection.

(9) If the sun's declination is 20° N., find by "Napier's rules" the time he will set in latitude 48° N.

(10) Prove that $\sin 45° = \cos 45°$.

Additional for Masters.

(11) On 25th June, 1929, at 22h. 00m. apparent time at ship, in longitude 2° 45′ E., the observed altitude of *Polaris* out of the meridian was 40° 03′, index error 1′ to subtract, height of eye 31 feet. Required the latitude.

(12) On 26th April, 1929, in longitude 113° 48′ E., the observed meridian altitude of the moon's upper limb was 53° 19′ South of the observer, index error 2′ to add, height of eye 25 feet. Required the latitude.

(13) While swinging the ship for deviations, the following compass bearings of a distant object were taken. Find its magnetic bearing, and thence the deviation on each point on which the bearings were observed.

Ship's head by standard compass.	Bearing of object by standard compass.	Deviation required.	Ship's head by standard compass.	Bearing of object by standard compass.	Deviation required.
North	N. 3° E.		South	N. 3° W.	
N.E.	N. 6 W.		S.W.	N. 6 E.	
East	N. 10 W.		West	N. 10 E.	
S.E.	N. 14 W.		N.W.	N. 14 E.	

Required magnetic bearing :—

Construct a curve of deviations on a Napier's diagram, using the deviations found above, and from it find the courses you would steer by the standard compass to make the following magnetic courses :—

Magnetic courses :— N. 17° E., S. 28° E., S. 53° W., N. 3° W.

Compass courses required :—

Supposing that you have steered the following courses by the standard compass, find from the above-mentioned curve the corresponding magnetic courses.

Compass courses :— N. 78° E., S. 42° E., S. 53° W., N. 87° E.

Magnetic courses required :—

You have taken the following compass bearings of two distant objects with the ship's head E.S.E. by compass. Find the corresponding magnetic bearings.

Compass bearings :— S. 82° E., N. 3° W.

Magnetic bearings required :—

(14) Required the initial and final great circle courses, also the distance along the great circle from Sydney in latitude 33° 52′ S., longitude 151° 18′ E. to San Francisco in latitude 37° 42′ N., longitude 123° W. Find also, the latitude and longitude of the vertex and the latitudes of the points where the great circle intersects the meridian of 160° E., and thence every tenth meridian to the destination.

Examination Paper VII.

(1) On 6th April, 1929, the observed altitude of the star *a* Ursæ Major (*Dubhe*) on the meridian below the pole was 19° 58.5′ north of the observer, height of eye 28 feet, index error 3′ 00″ to subtract. Required the latitude.

(2) On 6th April, 1929, in latitude by account 52° 28′ S., longitude 55° W., compute the approximate observed meridian altitude of *a* Argus (*Canopus*) below the pole as a guide to setting the sextant for observation, height of the eye 28 feet, and index error 3′ 00″ to subtract.

(3) On 23rd December, 1929, in latitude by account 18° 36′ N., longitude by account 114° E., the observed altitude of the star *a* Can. Maj. (*Sirius*) East of the meridian was 42° 40′, time by a chronometer 14h 53m 06s, which was fast for mean noon at Greenwich 18th October, 1929, 3m 47s, and losing 1.8 seconds daily. Height of eye 26 feet, index error of sextant 2.5′ to add. Required the longitude by chronometer.

(4) Supposing you are not familiar with the stars, and wish to take an observation, find the names (*from the Nautical Almanac*) of the stars not less bright than the second magnitude that will be within half an hour East of your meridian, above the pole and above the horizon, at about 03h 46m apparent time at ship on 23rd December, 1929, in latitude 40° 20′ N., and longitude 5° 30′ E. Required, also, approximately, the hour angle of each of the stars, and state also whether they will be to the North or South of your zenith when passing the meridian.

(5) On 24th December, 1929, at 18h 02m 10s apparent time at ship, in latitude 52° 20′ N., longitude 148° 18′ E., the star *a* Tauri (*Aldebaran*) bore by compass S. 81° 30′ E. Required the true azimuth and error of the compass by the Time Azimuth tables, and supposing the variation to be 6° 30′ W., required the deviation of the compass for the direction of the ship's head.

(6) On 13th June, 1929, in latitude by account 51° 28′ S., longitude 79° 16′ W., the observed altitude of the sun's L.L. near the meridian was 14° 35′ north of the observer, height of eye 40 feet, time by a watch 18h 09m 47s, which had been found to be fast of apparent time at ship 5h 23m 30s, but the ship had made 19′ difference of longitude to the Westward since the determination of the error on apparent time at ship. Required the latitude of the ship at the time of taking the observation; also required the latitude at noon, the ship having run 016°, 11 miles between noon and the time of taking the observation.

(7) On 20th May, 1929, at ship, being in latitude by account 4° S., longitude 85° W., required the approximate apparent time at ship when the star *a* Bootis (*Arcturus*) would be on the meridian.

(8) On 11th January, 1929, A.M. at ship, in latitude by account 46° 50′ N., longitude by account 153° 30′ E., when a chronometer (corrected) indicated mean time at Greenwich (10th January) 23h 24m 21s, the observed altitude of the sun's L.L. was 13° 30′, and again P.M. on the same day when the same chronometer (corrected) indicated 02h 42m 07s, the observed altitude of the sun's L.L. was 20° 32′, height of the eye at each observation being 30 feet. The ship having made 32 miles on a 258° course during the interval between the observations, required the line of position and true bearing of the sun when the first altitude was observed, and the position of the ship when the second altitude was observed. (*This double altitude may be worked by Sumner's method or Marcq St. Hilaire's method.*)

(9) A ship steaming N. 48° W. encounters a current setting S. 85° E. at 2 knots. Ship's speed 12 knots. Find the course and distance made good in one hour.

(10) Draw a figure and prove that $\tan A = \dfrac{\sec A \ \cos A}{\cot A}$

(11) Define the terms, hour angle, polar distance and zenith distance.

ADDITIONAL FOR MASTERS.

(12) On 21st March, 1929, in longitude 140° 20′ W., when a chronometer (corrected) indicated Mean time at Greenwich 12h 24m 30s, the observed altitude of the pole star out of the meridian was 49° 30′, height of the eye 21 feet. Required the latitude.

(13) On 19th June, 1929, in longitude 57° 45′ E., the observed meridian altitude of the moon's L.L. was 70° 40′ south of the observer, index error 3′ 20″ to add, height of the eye 28 feet. Required the latitude.

(14) Having taken the following compass bearings of a distant object, find the object's magnetic bearing and thence the deviation:—

MAGNETIC BEARING REQUIRED.

Ship's head by standard compass.	Bearing of distant object by standard compass.	Deviation Required.	Ship's head by standard compass.	Bearing of distant object by standard compass.	Deviation Required.
North	N. 34° W.		South	N. 66° W.	
N.E.	N. 47 W.		S.W.	N. 49 W.	
East	N. 64 W.		West	N. 36 W.	
S.E.	N. 73 W.		N.W.	N. 31 W.	

With the deviations as above, construct a curve of deviations on a Napier's diagram, and give the courses you would steer by the standard compass to make the following courses, magnetic:—

Magnetic Courses . . N.N.E. S.E. by E. W.S.W. N.W. by W.

Compass courses required:—

(15) Find the initial course and distance on the arc of a great circle from Y to Z

Lat of Y	34° 10′ S.	Long. of Y	25° 42′ E.
Lat. of Z	20 0 S.	Long. of Z	105 10 E.

Find the latitude and longitude of the vertex, and the latitude at which the track of the great circle intersects the meridians passing through the 40th degree of East longitude and every 20° of longitude in succession until arriving at Z. Explain briefly how the course and distance from one point to another is then found.

(16) Two buoys, A and B, are on the southern limit of a prohibited area. B is due East of A. A ship steering on a course parallel to a line joining the two buoys observes A bearing N. 50° E. and after steaming for 4 miles B was observed to bear N. 20° E. when the horizontal angle between A and B was 50°. Find the distance of the ship from B at the time of taking the second observation.

ANSWERS.

A. Plane Trigonometry (Page 44).

(1) Bearing of beacon from tower, S. 84° 39′ 18″ W. Distance of beacon from observer = 2·871 miles.
(2) Distance of vessel from nearest point = 7·437 miles. Distance between the points = 2·638 miles.
(3) Height of lighthouse = 43·56 feet.
(4) Other vessel's speed = 19·39 knots.
(5) Vessel's course = N. 3° 48′ 4″ E.
(6) Distance made good = 5·102 miles. Distance sailed = 13·077 miles.
(7) Ship's course = S. 50° 24′ 55″ E.
Distance off at 2nd bearing = 4·286 miles.
(8) Ship's course = N. 87° 42′ 20″ E.
(9) Distance from C = ·732 mile.
(10) Vessel's course, N. 54° 27′ 57″ E. or N. 9° 27′ 57″ W. Distance steamed, 7·211 miles. Distance from headlands, 4·366 and 7·87 miles.
(11) Angle to set the sextant at = 3° 46′ 4″.
(12) Courses (1) S.E.; (2) N. 84° 50′ W.; (3) N. 0° 23′ E.
(13) Distance apart when abeam = ·76 mile.
(14) Ship's course, N. 69° 51′ 40″ E. Distance, 3·855 miles.
(15) A's bearing = N. 1° 35′ 55″ W.; B's bearing, N. 86° 26′ 53″ E.
(16) Distance between objects = 2·944 miles.
(17) B's speed = 9·332 knots.
(18) Course to steer, N. 57° 21′ W.; time taken, 62·67 minutes.
(19) Ratio between heights of beacons = 1·0 is to 1·483.
(20) Distance from cliffs = 6·731 and 8·654 miles.
(21) Distance apart = 10·453 miles.
(22) Bearing of B from A = S. 24° 43′ 32″ W.; distance, 8·45 miles.
(23) B's course, N. 70° 42′ 31″ E.; speed, 21·188 knots.
(24) Distance, 3·507 cables.

B. Spherical Trigonometry (Page 56).

			°	′	″			°	′	″			°	′	″
(1)		a =	77	50	22;		B =	74	0	0;		C =	53	41	52.
(2)		x =	74	59	58;		y =	39	59	59;		z =	70	15	9.
(3)		B =	110	40	1;		c =	127	44	14;		a =	74	43	21.
(4)		O =	129	12	55;		m =	63	42	45;		o =	136	0	1.
	or	O =	50	47	5;		m =	116	17	15;		o =	43	59	59.
(5)		C =	88	55	41;		a =	101	22	3;		B =	84	34	36.
(6)	Sides	=	41	28	38	and		119	59	59;	angle		110	55	34.
(7)	Angles	=	78	34	17	and		107	37	52;	hypotenuse,		93	41	1.
(8)		C =	90		;		c =	90		;		b =	90.		

(9) No, it is indeterminable, for if we imagine C to be at the pole of the earth and "c" an arc of the equator, then we have at once $A = 90°$, $B = 90°$, "a," $= 90°$, "b" $= 90°$. Angle C = side c, but both may have any value less than 180°.

		°	′	″		°	′	″		°	′	″
(10)	K =	67	27	6 ;	l =	77	59	59 ;	m =	85	20	25.
(11)	A =	83	3	8 ;	B =	152	34	3 ;	c =	86	22	24.
(12)	a =	75	19	57 ;	b =	54	28	;	c =	64	10	17.
(13)	b =	117	30	57 ;	C =	32	29	59 ;	a =	121	42	5.
(14)	c =	76	0	53 ;	A =	43	36	49 ;	a =	42	0	59.
or	c =	103	59	7 ;	A =	136	23	11 ;	a =	137	59	1.
(15)	b =	99	49	29 ;	A =	86	47	11 ;	c =	162	3	44.
(16)	C =	103	56	30 ;	A =	114	30	46 ;	b =	122	59	1.
(17)	a =	44	54	31 ;	C =	44	19	25 ;	c =	34	35	11.
(18)	a =	45	37	58 ;	B =	31	52	0 ;	c =	40	57	58.
(19)	A =	80	25	30 ;	C =	17	54	29 ;	c =	15	12	15.

C. Spherical Trigonometry (Page 60).

(1) True amplitude, W. 31° 23′ S. Time of sunset, 4h. 28m. 8s. P.M.
(2) Sun's declination, 9° N.
(3) Time, 7h. 15m. 32s. A.M.
(4) Time below horizon, 10h. 36m. 56s.
(5) Star's right ascension, 7h. 35m. 36s.
(6) Star's altitude, 55° 51′ 15″.
(7) Difference between right ascensions, 59m. 56s.
(8) Latitude, 69° 31′ 34″ N.
(9) Latitude, 56° 33′ 36″ N.
(10) True bearing of light, N. 88° 8′ 26″ E.

1. Meridian Altitude Star (Page 84).

No.	Declination.	Approx. Obs. Alt.	True Altitude.	Latitude.
	° ′		° ′	° ′
1	28 33·0 N.		72 4·3 S.	46 28·7 N.
2	16 37·0 S.		51 56·1 N.	54 40·9 S.
3	32 2·8 N.		28 30·7 N.	29 26·5 S.
4	12 18·9 N.	° ′	35 12·4 N.	42 28·7 S.
5	8 40·9 N.	64 58·3 N.	64 49·1 N.	
6	38 42·6 N.	80 16·9 S.	80 12·6 S.	
7	12 18·9 N.	35 21·4 N.	35 17·1 N.	
8	57 36·2 S.	32 32·1 S.	32 23·8 S.	

1*a*. Mer. Alt. Star below the Pole (Page 90).

(1) Polar dist. 37° 20·6′, true alt. 14° 4·6′ S., lat. 51° 25·2′ S.
(2) Polar dist. 44° 58·8′, true alt. 17° 30·4′ N., lat. 62° 29·2′ N.
(3) Polar dist. 27° 52·4′, approx. true alt. 21° 59·6′, approx. obs. alt. 22° 9·1′ N.
(4) Polar dist. 21° 5·6′, approx. true alt. 30° 4·4′, approx. obs. alt. 30° 9·8′ S.

2. Longitude by Star (Page 96).

No.	G.M.T.				*P O*		*Z O*(*p*)		R.			Hour Angle.			Longitude.		
	d.	h.	m.	s.	°	′	°	′	h.	m.	s.	h.	m.	s.	°	′	″
1	11	19	05	05	73	22·9	66	52·7	07	23	11	4	54	46 W.	137	8	0 E.
2	12	21	19	28	100	47·6	52	10·7	15	20	34	2	39	59 E.	29	38	15 W.
3	23	08	00	00	73	37·9	50	14·9	12	01	18	3	30	34 W.	179	43	15 W.
4	24	19	18	44	60	00·3	35	53·5	18	09	49	2	43	27 W.	177	50	15 W.
5	24	11	49	06	81	19·1	55	36·8	00	11	18	3	46	21 W.	173	19	30 E.
6	23	20	00	35	97	23·8	73	47·1	06	07	29	4	3	6 E.	4	56	45 W.

3. To find the R.A.M. (Page 100).

No.	Greenwich Time.				E.			R.			S.M.T.				R.A.M.		
	d.	h.	m.	s.	h.	m.	s.	h.	m.	s.	d.	h.	m.	s.	h.	m.	s.
1	26	18	19	20				00	20	15		Given			03	46	15
2	19	13	31	52	12	00	50	13	48	39		01	58	10	15	46	49
3	7	00	39	09				07	04	23		Given			04	02	48
4	22	01	32	00	11	52	48	11	56	17		05	17	12	17	13	29
5		Given						17	30	56	14	19	49	00	13	19	56
6		Given						06	18	12	26	04	53	48	11	12	00

4. Stars Near the Meridian (Page 108).

1. E. 11h. 52m. 32s. R. 07h. 17m. 11s., S.M.T. 03h. 47m. 28s., R.A.M. 11h. 04m. 39s.
   - α Leonis (*Regulus*) has crossed meridian North, hour angle 1h. 0m. W.
   - γ Leonis ,, ,, North, ,, 0h. 49m. W.
   - β Leonis (*Denebola*) will cross meridian North, ,, 0h. 40m. E.
   - α Crucis ,, ,, South, ,, 1h. 18m. E.
   - γ Crucis ,, ,, South, ,, 1h. 22m. E.

2. S.M.T. 19h. 04h. 31m. 18s., R. 11h. 46m. 46s., R.A.M. 16h. 18m. 04s.
   - α Centauri has crossed meridian South, hour angle, 1h. 43 m. W.
   - α Scorpii (*Antares*) will cross meridian South, ,, 0h. 7m. E.
   - α Trianguli Australis ,, ,, South, ,, 0h. 23m. E.
   - λ Scorpii ,, ,, South, ,, 1h. 11m. E.
   - θ Scorpii ,, ,, South, ,, 1h. 14m. E.

3. G.M.T. 19d. 12h. 48m. 00s., R. 13h. 48m. 32s., R.A.M. 19h. 28m. 32s.
   - α Aquilæ (*Altair*) will cross meridian North, hour angle, 0h. 18m. E.
   - α Pavonis ,, ,, South, ,, 0h. 51m. E.

4. E. 12h. 03m. 44s., R. 15h. 13m. 59s., S.M.T. 07h. 36m. 16s., R.A.M. 22h. 50m. 15s.
   - α Piscis Aust. (*Fomalhaut*) will cross meridian North, hour angle, 0h. 4m. E.
   - α Phœnicis ,, ,, North, ,, 1h. 33m. E.
   - α Eridani (*Achernar*) ,, ,, South, ,, 2h. 45m. E.

5. G.M.T. 23d. 10h. 50m. 00s., R. 00h. 07m. 12s., R.A.M. 00h. 37m. 12s.
   - α Andromedæ (*Alpheratz*) has crossed meridian South, hour angle, 0h. 32m. W.
   - α Cassiopeiæ (*Schedar*) on the meridian to the Northward.
   - β Ceti will cross meridian South, hour angle, 0h. 3m. E.
   - α Ursa Minoris (*Polaris*) ,, ,, North, ,, 1h. 0m. E.

6. S.M.T. 20d. 05h. 40m. 00s., R. 23h. 56m. 00s., R.A.M. 05h. 36m. 00s.
   - α Orionis (*Betelguese*) will cross meridian North, hour angle, 0h. 15m. E.
   - α Argus (*Canopus*) ,, ,, South, ,, 0h. 46m. E.
   - α Canis Majoris (*Sirius*) ,, ,, North, ,, 1h. 6m. E.

5. Star Time Azimuths (Page 114).

	No. 1.	No. 2.
	d. h. m. s.	d. h. m. s.
G.A.T.,	10 20 07 20	19 08 16 40
E.,	11 52 18	11 52 00
R.,	07 19 25	11 45 34
S.M.T.,	01 21 42	19 18 00
R.A.M.,	08 41 07	07 03 35
Hour angle,	4 9 16 W.	3 1 2 E.
True az.,	S. 119·5° W.	N. 112·8° E.
Error,	9·5° W.	19·8° E.
Dev.,	6·5° E.	15·6° E.

	No. 3.	No. 4.
	d. h. m. s.	d. h. m. s.
G.M.T.,	27 01 14 00	4 01 16 00
R.,	00 21 23	20 48 30
R.A.M.,	00 07 23	23 58 30
Hour angle,	5 13 58 E.	4 33 22 E.
True az.,	N. 91° E.	N. 87° E.
Error,	0	3° E.
Dev.,	20° E.	8° E.

	No. 5.	No. 6.
	d. h. m. s.	d. h. m. s.
S.M.T.,	20 23 20 00	15 21 57 15
R.,	15 52 57	13 34 14
R.A.M.,	15 12 57	11 31 29
Hour angle,	4 34 23 E.	3 55 54 W.
True az.,	S. 111° E.	N. 112·2° W.
Error,	21° W.	2·8° E.
Dev.,	21° W.	14·8° E.

6. Sun Reduction (Mean Time) (Page 122).

	No. 1.	No. 2.	No. 3.
	d. h. m. s.	d. h. m. s.	d. h. m. s.
S.M.T.,	7 11 56 21	15 12 17 56	15 11 45 36
E.,	11 53 38	12 03 47	11 59 55
H.A.T.S.,	23 49 59	0 21 43	23 45 31
Time from noon,	0 10 1	0 21 43	0 14 29
	° ′	° ′	° ′
Polar dist.,	67 37·2	71 5·7	113 17·1
Obs. zen. dist.,	33 55·1 S.	29 59·4 N.	52 18·8 S.
Mer. zen. dist.,	33 52·2 S.	29 39·9 N.	52 11·75 S.
Lat. sights,	56 15·0 S.	48 34·2 N.	28 54·65 S.
Lat. noon,	56 14·4 S.	48 30·1 N.	

	No. 4.
	d. h. m. s.
S.M.T.,	26 11 24 30
E.,	11 59 43
H.A.T.S.,	23 24 13
Time from noon,	0 35 47
	° ′
Polar dist.,	113 23·8
Obs. zen. dist.,	70 29·7 N.
Mer. zen. dist.,	70 1·8 N.
Lat. sights,	46 38·0 N.
Lat. noon,	46 31·0 N.

7. Sun Reduction (Apparent Time) (Page 123).

	No. 5.				No. 6.				No. 7.			
	d.	h.	m.	s.	d.	h.	m.	s.	d.	h.	m.	s.
S.A.T.,	.21	11	34	26	24	12	22	48	24	11	22	01
G.A.T.,	21	00	40	46	24	10	02	00	24	16	15	45
E.,		12	03	37		11	57	53		12	00	23
H.A.T.S.,		23	34	26		00	22	48		23	22	01
G.M.T.,	21	00	37	09	24	10	04	07	24	16	15	22
Time from noon,			25	34			22	48			37	59
	°	′			°	′			°	′		
Polar dist.,	110	2·9			66	34·3			113	25·7		
Obs. zen. dist.,	55	8·0	S.		23	2·0	N.		49	40·8	N.	
Mer. zen. dist.,	54	48·0	S.		22	34·0	N.		48	49·2	N.	
Lat. sights,	34	45·1	S.		45	59·7	N.		25	23·5	N.	
Lat. noon,	34	47·0	S.		46	0·9	N.					

8. Star Reduction (Mean Time) (Page 128).

	No. 1.				No. 2.				No. 3.			
	d.	h.	m.	s.	d.	h.	m.	s.	d.	h.	m.	s.
S.M.T.,	10	05	19	16	9	04	30	44	19	04	51	12
R.,		07	17	20		15	04	17		11	46	25
R.A.M.,		12	36	36		19	35	01		16	37	37
Hour angle,			13	58 W.			12	19 E.			12	34 W.
	°	′			°	′			°	′		
Obs. zen. dist.,	48	21·1	N.		40	2·4	N.		62	46·1	N.	
Mer. zen. dist.,	48	17·3	N.		39	57·4	N.		62	41·9	N.	
Latitude,	14	24·7	S.		48	38·0	N.		36	25·3	N.	

9. Star Reduction (Apparent Time) (Page 128).

	No. 4.				No. 5.			
	d.	h.	m.	s.	d.	h.	m.	s.
S.A.T.,	23	01	52	02	28	23	55	42
G.A.T.,	23	03	38	50	29	08	44	42
E.,		12	07	24		11	58	03
R.,		00	06	01		06	29	17
H.A.T.S.,		13	52	02		11	55	42
S.M.T.,		01	44	38		23	57	39
R.A.M.,		01	50	39		06	26	56
Hour angle,			15	31 W.			15	08 E.
	°	′			°	′		
Obs. zen. dist.,	57	20·4	N.		53	24·9	N.	
Mer. zen. dist.,	57	15·5	N.		53	17·7	N.	
Latitude,	0	19·9	S.		36	40·7	N.	

10. Star on Meridian (Mean Time) (Page 135).

No.	Approx. G.M.T.				R.			Mean time at ship.				Civil time.			
	d.	h.	m.	s.	h.	m.	s.	d.	h.	m.	s.	h.	m.	s.	
1	4	18	31	34	06	55	30	5	05	27	08	5	27	8	A.M.
2	19	07	39	25	11	45	28	18	22	19	09	10	19	9	P.M.
3	14	17	36	37	13	29	33	15	05	04	59	5	4	59	A.M.

11. Star on Meridian (Apparent Time) (Page 135).

No.	Approx. G.M.T.				R.			E.			Appt. time at ship.				Civil time.			
	d.	h.	m.	s.	h.	m.	s.	h.	m.	s.	d.	h.	m.	s.	h.	m.	s.	
4	11	02	39	02	15	13	36	12	03	44	11	01	31	20	1	31	20	A.M.
5	24	10	28	27	18	08	22	11	57	53	24	22	14	37	10	14	37	P.M.
6	8	16	32	33	21	06	47	11	54	28	8	06	06	57	6	6	57	A.M.

12. Star on Meridian (Inspection) (Page 137).

No. 1. 5h. 20m.
No. 2. 22h. 13m.
No. 3. 5h. 4m.
No. 4. 1h. 31m.
No. 5. 22h. 13m.
No. 6. 6h. 8m.

13. Double Altitude—Sumner's Method (Page 148).

No. 1.

First Observation.

d. h. m. s.
G.M.T., . 7 09 08 40
E., . . 11 54 18
$P\,Z$ 40° 10′ and 40° 21·7′.
$P\,X$ 73° 28·2′.
$Z\,X$ 51° 32·3′ = p.

A { Log. hav. 9·23766
H.A.T.S. 20h. 43m. 28s.
Long. 4° 52′ 30″ W.

B { Log hav. 9·23973
H.A.T.S. 20h. 42m. 58s.
Long. 5° 0′ 0″ W.

Second Observation.

d. h. m. s.
G.M.T. . 7 15 15 55
E., . . 11 54 20
$P\,Z$ 40° 10′ and 40° 21·7′.
$P\,Y$ 73° 32·4′.
$Z\,Y$ 48° 29·2′ = p.

C { Log hav. 9·14392
H.A.T.S. 2h. 55m. 19s.
Long. 3° 44′ 0″ W.

D { Log hav. 9·14685
H.A.T.S. 2h. 55m. 56s.
Long. 3° 34′ 45″ W.

Answer.

Line of position, 1st obs. N. 23° E. and S. 23° W.

Sun's true bearing, 2nd obs. S. 56° W.

Lat. 50° 1½′ N.
Long. 3° 56′ W.

No. 2.

d. h. m. s.
G.M.T., . 23 22 19 10
E., . . 12 07 40
$P\,Z$ 38° 45′ and 38° 25′.
$P\,X$ 90° 09·2′.
$Z\,X$ 60° 45·3′ = p.

A { Log hav. 9·03376
H.A.T.S. 21h. 26m. 27s.
Long. 164° 54′ 15″ E.

B { Log hav. 9·02202
H.A.T.S. 21h. 28m. 35s.
Long. 165° 26′ 15″ E.

d. h. m. s.
G.M.T., 24 01 56 49
E., 12 07 43
$P\,Z$ 38° 45′ and 38° 25′.
$P\,Y$ 90° 12·8′.
$Z\,Y$ 53° 13·9′ = p.

C { Log hav. 8·29015
H.A.T.S. 1 hr. 4m. 14s.
Long. 164° 55′ 30″ E.

D { Log hav. 8·20356
H.A.T.S. 0h. 58m. 6s.
Long. 163° 23′ 30″ E.

Line of position, 1st obs., N. 45° E. and S. 45° W.

Sun's true bearing, 1st obs., S. 45° E.

Lat. 51° 29′ N.
Long. 163° 50′ E.

No. 3.

d. h. m. s.
G.M.T., . 15 02 02 19
E., . . 11 59 54
$P\,Z$ 39° 48′ and 40° 09·6′.
$P\,X$ 66° 42·6.
$Z\,X$ 35° 32·6′ = p.

A { Log hav. 8·82194
H.A.T.S. 1h. 59m. 26s.
Long. 179° 18′ 15″ E.

B { Log hav. 8·83413
H.A.T.S. 2h. 1m. 9s.
Long. 179° 44′ 0″ E.

d. h. m. s.
G.M.T., 15 06 32 28
E., 11 59 51
$P\,Z$ 39° 48′ and 40° 09·6′.
$P\,Y$ 66° 42·2′.
$Z\,Y$ 77° 33·2′ = p.

C { Log hav. 9·75979
H.A.T.S. 6h. 34m. 35s.
Long. 179° 26′ 0″ W.

D { Log hav. 9·75833
H.A.T.S. 6h. 33m. 41s.
Long. 179° 39′ 30″ W.

Line of position, 1st obs., N. 38° W. and S. 38° E.

Sun's true bearing, 2nd obs., N. 82° W.

Lat. 49° 42′ N.
Long. 179° 31′ W.

14. Sumner's Method projected on Chart (Page 149).

No.1.

Line of position at first observation, N. 42° E. and S. 42° W.
Sun's true bearing at first observation, S. 48° E.
Ship's position at second observation, Lat. 50° 13′ N., Long. 1° 18′ W.

No. 2.

Line of position at first observation, N. 27° E., and S. 27° W.
Sun's true bearing at second observation, S. 28° E.
Ship's position at second observation, Lat. 51° 36′ N., Long. 1° 35′ E.

No. 3.

Line of position at first observation, N. 33° E. and S. 33° W.
Sun's true bearing at second observation, S. 57° W.
Ship's position at second observation, Lat. 50° 28′ N., Long. 0° 13′ W.

15. **Marcq. St. Hilaire** (page 164).

No. 1 (Sun).

	First observation.	Second Observation.
Lat. D.R.	49° 0′ N., . .	49° 15′ N.
Long. D.R.	170 0 E., . .	169 10 E.

	d.	h.	m.	s.	d.	h.	m.	s.
G.M.T.,	20	19	06	52	20	23	06	50
E.,		12	03	38		12	03	38
H.A.T.S.,		18	30	30		22	27	08
P.,		5	29	30		1	32	52

P Z,	41° 00′	*P Z*,	40° 44·8′
P X,	70 00	*P Y*,	69 58

Sun's bearing	N. 82° E.	. .	N. 140° E.
Calculated alt.,	19 52·5′	. .	55 23·5′
True alt.,	20 6·5	. .	55 41·0
Intercept towards	14′	Intercept towards	17·5′

Ship's position 2nd obs. { Lat. 49° 5′ N. / Long. 169 34 E.

No. 2 (Sun).

	First Observation.	Second Observation.
	42° 0′ S., ...	41° 45′ S.
	149 0 E., ...	149 35 E.

	d.	h.	m.	s.	d.	h.	m.	s.
	20	00	07	40	20	04	04	52
		12	06	17		12	06	21
		22	09	57		2	09	33
		1	50	03		2	09	33

P Z,	48° 00′	*P Z*,	48° 15′
P X,	91 22·4	*P Y*,	91 18·6

	S. 143° E.	S. 137° W.
	40 00·4′	37 55·5′
	40 09·3	37 50·7
	Intercept towards 8·9′.	Intercept away 4·8′.

Line of position 2nd obs., N. 47° E. and S. 47° W.
Sun's bearing 2nd obs., N. 43 W.
Ship's position 2nd obs. { Lat. 41° 42′ S. / Long., 149 49 E.

No. 3 (Sun).

	First Observation.	Second Observation.
Lat. D.R.,	50° 20′ N., . .	49° 58′ N.
Long. D.R.,	33 30 W., . .	34 14 W.

	d.	h.	m.	s.	d.	h.	m.	s.
G.M.T.,	15	13	00	00	15	16	24	15
E.,		11	59	54		11	59	56
H.A.T.S.,		22	45	54		2	07	15
P.,		1	14	06		2	07	15

P Z,	39° 40′	*P Z*,	40° 02′
P X,	80 17·6	*P Y*,	80 14·5

Sun's bearing	N. 152° E.	. .	N. 135° W.
Calculated alt.	46 35′	. .	41 57′
True alt.,	46 26·9	. .	41 47·7
Intercept away	8·1	Intercept away	9·3

Ship's position 2nd obs. { Lat. 50° 9′ N. / Long. 34 10 W.

No. 4 (Sun and star).

	First Observation.	Second Observation.
	42° 30′ S., ...	42° 26′ S.
	144 10 E., ...	143 16 E.

	d.	h.	m.	s.	d.	h.	m.	s.
S.M.T.,	4	15	35	59	4	20	01	12
E.,		11	54	00				
R.,						20	50	00
H.A.T.S.,		3	29	59				
P,		3	29	59			40	28 E.

P Z,	47° 30′	*P Z*,	47° 34′
P X,	107 22·7	*P Y*,	102 36·7

Sun's bg.	S. 129° W. .	Star's bg.	S.169° E.
Calculated alt.	13° 5·8′ .	. .	34 10·6′
True alt.	13 17·6 .	. .	34 21·3
Intercept towards	11·8′.	Intercept towards	10·7′.

Ship's position 2nd obs. { Lat. 42° 14′ S. / Long. 143 9 E.

No. 5. (Simultaneous Altitudes).

G.M.T. 14d. 06h. 18m. 10s., S.M.T. 14d. 03h. 28m. 10s., R. 13h. 27m. 45s., R.A.M. 16h. 55m. 55s.

Observation of Altair.

Hour angle 2h. 51m. 24s. E., *P Z* 39° 30′, *P X* 81° 19·5′, star's bearing N. 125° E., calculated alt. 35° 16·0′, true alt. 35° 38·0′, intercept towards 22′.

Observation of Arcturus.

Hour angle 2h. 43m. 28s. W., *P Z* 39° 30′, *P Y* 70° 27·1′, star's bearing N. 118° W., calculated alt. 45° 21·5′, true alt, 44° 56·3′, intercept away 25·2′.
Ship's position, Lat. 50° 31′ N., Long. 41° 45′ W.

No. 6.

First Observation. (*Procyon*)		Second Observation. (*Procyon*)	
Lat. D.R.,	51° 30′ N.		51° 0′ N.
Long. D.R.,	160 12 W.,		160,59·5 W.
	d. h. m. s.		d. h. m. s.
G.M.T.,	20 05 10 47		20 09 10 40
S.M.T.,	19 18 29 15		19 22 26 44
R.,	11 49 00		11 49 40
R.A.M.,	6 18 59		10 16 24
Hour angle,	1 16 37 E.		2 40 48 W.
P Z,	38° 30′	*P Z*,	39° 00′
P X,	84 35·5	*P Y*,	84 35·5
Star's bearing	N. 152° E.		N. 130° W.
Calculated alt.,	41 14·3′		33 29·3′
True alt.,	40 46·0		33 41·7
Intercept away	28·3	Intercept towards	12·4

Ship's position 2nd obs. { Lat. 51° 16′ N. / Long. 161 45 W.

No. 7.

First Observation. (*Rigel*)		Second Observation. (*Spica*)	
	50° 0′ N.		49° 27·6′ N.
	180 0 E.,		179 23·6 E.
	d. h. m. s.		d. h. m. s.
	2 11 57 24		2 16 27 41
	2 23 57 24		3 04 25 15
	06 46 32		06 47 16·5
	06 43 56		11 12 31·5
	1 32 48 W.		2 8 54·5
P Z,	40° 00′	*P Z*,	40° 32·4′
P X,	98 17	*P Y*,	100 47·4
	N. 152° W.		N. 144° E.
	28 18·8		23 26·7
	27 58·9		22 49·8
Intercept away	19·9	Intercept away	36·9

Ship's position 2nd obs. { Lat. 50° 0′ N. / Long. 178 55 E.

17. Freight and Commission (Page 187).

No. 1.

Gross Freight,	£3,255	0	0
Commission,	130	4	0
Net Freight,	£3,124	16	0

No. 2.

Gross Freight,	£2,781	12	0
Commission,	83	8	11
Net Freight,	£2,698	3	1

No. 3.

Gross Freight,	£2,840	0	0
Commission,	142	0	0
Net Freight,	£2,698	0	0

No. 4.

Gross Freight,	£5,240	0	0
Commission,	209	12	0
Net Freight,	£5,030	8	0

No. 5.

Gross Freight,	£3,368	15	0
Commission,	67	7	6
Net Freight,	£3,301	7	6

No. 6.

Gross Freight,	£2,850	0	0
Commission,	71	5	0
Net Freight,	£2,778	15	0

No. 7.

Gross Freight (R), 26880·0

Gross Freight,	£1,734	3	10½
Commission,	56	7	2½
Net Freight,	£1,677	16	8

No. 8.

Gr. Freight (Mks.), 58563·00

Gross Freight,	£2,849	15	7½
Commission,	113	19	10
Net Freight,	£2,735	15	9½

No. 9.

Gross Freight ($), 42780·71

Gross Freight,	£8,820	15	4
Commission,	308	14	6
Net Freight,	£8,512	0	10

No. 10.

Gr. Freight (Frs.), 50400·00

Gross Freight,	£1,968	15	0
Commission,	98	8	9
Net Freight,	£1,870	6	3

18. Capacity of Hold or Bunker (Page 189).

No. 1. 3,696 cubic feet, . . . 88 tons.
No. 2. 3,696 ,, . . . 88 ,,
No. 3. 1,980 ,, . . . 44 ,,
No. 4. 3,348 ,, . . . 77 tons 17·2 cwts.
No. 5. 35 feet.
No. 6. 33 feet 4 inches.
No. 7. 33 feet 9 inches.
No. 8. 47 feet 8·7 inches.

19. Capacity of Tank or Cylinder (Page 191).

1. 502·7 cubic feet. 3,142 gallons.
2. 197·5 cubic feet. 5·485 tons fresh water.
3. 187·8 cubic feet. 5·366 tons salt water.
4. 346·4 cubic feet. 9·621 tons.

20. Ship's Draught (Page 192).

	Feet.	Inches.	
No. 1,	19	4·3	
No. 2,	22	3·1	
No. 3,	24	0·4	Ship would rise 6·4 ins.
No. 4,	17	3·0	

No. 5, . . 2·7 inches.
No. 6, . . 2·8 inches.
No. 7, . . 1·8 inches.
No. 8, . . 4·3 inches.

21. Latitude by Pole Star (Page 271).

	No. 1.				No. 2.			
	d.	h.	m.	s.	d.	h.	m.	s.
G.M.T.,	18	5	24	0	18	9	28	20
R.,		11	41	09		13	44	02
Local sidereal time,		14	57	09		13	23	02
Hour angle,		10	37	53 E.		11	48	7 W.
		°	′			°	′	
True altitude,		45	13·8			34	50·5	
Correction I.,		+ 1	00·0			+ 1	03·9	
Correction II.,		+	0·1				0	
Correction III.,		+	0·4			+	0·6	
Latitude,		46	14·3 N.			35	55·0 N.	

	No. 3.				No. 4.			
	d.	h.	m.	s.	d.	h.	m.	s.
E.,		11	58	54		11	54	09
G.M.T.,	19	17	02	54	6	00	36	31
R.,		17	49	44		20	56	16
Local sidereal time,		21	53	49		19	30	07
Hour angle,		3	41	45 E.		6	6	37 E.
		°	′			°	′	
True altitude,		50	53·8			61	03·1	
Correction I.,		—	36·2			+	01·7	
Correction II.,		+	·5			+	01·1	
Correction III.,		+	·5			+	0·1	
Latitude,		50	18·6 N.			61	06·0 N.	

	No. 5.				No. 6.			
	d.	h.	m.	s.	d.	h.	m.	s.
G.M.T.,	23	15	17	40	9	22	53	40
S.M.T.,	23	05	19	40	10	00	14	20
R.,		06	06	42		07	15	56
Local sidereal time,		11	26	22		07	30	16
Hour angle,		9	49	22 W.		5	54	19 W.
		°	′			°	′	
True altitude,		42	15·5			35	54·9	
Correction I.,	+		54·1			—	01·6	
Correction II.,	+		00·2			+	0·4	
Correction III.,	—		0·1				0	
Latitude,		43	09·7 N.			35	53·7 N.	

22. **Moon's Meridian Passage** (Page 273).

	Diff.	Corr. for Long.	S.M.T.			G.M.T.		
	m.	m.	d.	h.	m.	d.	h.	m.
1.	50	— 17·5	19	18	35·5	19	10	12·5
2.	65	+ 24·7	23	23	19·7	24	08	26·4
3.	48	— 6·0	27	02	17	26	23	17
4.	51	+ 7·2	28	03	19·2	28	06	41·9
5.	44	— 4·9	18	21	24·1	18	18	40·8
6.	51	+ 3·0	21	23	56	22	01	19·3
7.			23	00	44	23	00	44

23. **Meridian Altitude Moon** (Page 279).

	No. 1.			No. 2.			No. 3.		
Diff. 1 day,	48m.			63m.			47m.		
Corr. for long.,	+ 8·0			— 14·0			+ 19·5		
	d.	h.	m.	d.	h.	m.	d.	h.	m.
S.M.T.,	26	01	43	22	21	36	17	17	35·5
G.M.T.,	26	05	43	22	16	16	18	03	37·5
	°	′		°	′		°	′	
Declination,	21	27·4 S.		25	43·8 N.		5	30·4 N.	
Semi-diameter,		15·1			16·7			16·0	
Horizontal parallax,		54·5			60·6			58·0	
Parallax in alt.,		30·8			50·3			40·4	
True altitude,	56	08·5 N.		34	41·8 N.		46	30·1 S.	
Latitude,	55	18·9 S.		29	34·4 S.		49	00·3 N.	

	No. 4.	No. 5.	No. 6.
Diff. 1 day,	49m.	50 m.	...
Corr. for long.,	− 19·1	+ 2·8	...
	d. h. m.	d. h. m.	d. h. m.
S.M.T.,	27 02 03·9	23 00 46·8	23 22 55
G.M.T.,	26 16 42·5	23 02 06·8	23 22 55
	° ′	° ′	° ′
Declination,	22 57·5 S.	26 57·0 S.	26 16·2 N.
Semi-diameter,	15·0	14·9	16·7
Horizontal parallax,	54·4	54·0	60·5
Parallax in alt.,	24·9	24·6	29·1
True altitude,	63 08·0 S.	63 19·1 S.	61 43·1 S.
Latitude,	3 54·5 N.	0 16·1 S.	54 33·1 N.

24. **Napier's Diagram** (Page 284).

1. Magnetic bearing—S. 54° W.
Deviations—21° W. 10° W. 2° W. 4° E. 20° E. 23° E. 5° E. 17° W.
Compass courses—N. 1° W. S. 31° E. N. 53° W. S. 67° E.
Magnetic courses—N. 7° E. N. 62° E. S. 45° W. S. 87° W.
Magnetic bearings—S. 43° E. and N. 31° W.

2. Magnetic bearing—S. 8° E.
Deviations—12° E. 18° E. 10° E. 6° W. 10° W. 14° W. 9° W. 3° W.
Compass courses—N. 8° E. N. 52° E. S. 13° E. N. 62° W.
Magnetic courses—N. 72° E. S. 44° W. N. 34° W. N. 9° E.
Magnetic bearings—N. 36° E. and N. 54° W.

3. Magnetic bearing—North.
Deviations—3° W. 17° E. 20° E. 15° E. 3° E. 9° W. 21° W. 22° W.
Compass courses—N. 13° E. S. 41° E. S. 70° W. N. 1° E.
Magnetic courses—S. 82° E., S. 29° E. S. 28° W. S. 72° E.
Magnetic bearings—S. 64° E. and N. 13° E.

4. Magnetic bearing, N. 53° E.
Deviations, 4° W., 18° E., 22° E., 14° E., 3° E., 11° W., 22° W., 21° W.
Compass courses required—N. 49° E., S. 89° E., S. 89° W., N. 46° W.
Magnetic courses required—S. 79° E., S. 39° E., S. 50° W., N. 52° W.
Magnetic bearings, N. 44° E. and N. 57° W.

25. **Great Circle Sailing** (Page 294).

1. Initial course S. 69° 50′ W., final course S. 38° 26′ W., distance 3,433·7 miles, latitude of vertex 52° 44′ N., longitude of vertex 20° 28′ E.

Position of points on great circle :—

C. Long. 15° 12′ W. Lat. 46° 53′ N.
D. Long. 25° 12′ W. Lat. 42° 34′ N.
E. Long. 35° 12′ W. Lat. 36° 33′ N.
F. Long. 45° 12′ W. Lat. 28° 26′ N.
G. Long. 55° 12′ W. Lat. 18° 1′ N.

2. Initial course N. 50° 47·3′ W., final course N. 87° 8·5′ W., distance 2,269·4 miles, latitude of vertex 51° 43·5′ N., longitude of vertex 166° 21·5′ E.

Position of points :—

C. Long. 150° W. Lat. 42° 31·4′ N.
D. Long. 160° W. Lat. 46° 32′ N.
E. Long. 170° W. Lat. 49° 15·5′ N.
F. Long. 180. Lat. 50° 55·4′ N.

3. Initial course N. 60° 0′ E., final course N. 46°·28′ E., distance 3913·9 miles, latitude of vertex 44° 8′ S., longitude of vertex 20° 23′ W.

Position of points :—

C. Long. 35° 30′ E. Lat. 28° 33′ S.
D. Long. 45° 30′ E. Lat. 21° 37′ S.
E. Long. 55° 30′ E. Lat. 13° 19′ S.
F. Long. 65° 30′ E. Lat. 3° 59′ S.
G. Long. 75° 30′ E. Lat. 5° 41′ N.

4. Initial course S. 86° 43½′ E., final course N. 56° 4½′ E., distance 4,975 miles, latitude of vertex 34° 30′ S., longitude of vertex 24° 16½′ E.

Position of points :—

C. Long. 34° 16½′ E. Lat. 34° 5½′ S.
D. Long. 44° 16½′ E. Lat. 32° 51½′ S.
E. Long. 54° 16½′ E. Lat. 30° 45½′ S.
F. Long. 64° 16½′ E. Lat. 27° 46′ S.
G. Long. 74° 16½′ E. Lat. 23° 50′ S.
H. Long. 84° 16½′ E. Lat. 18° 58′ S.
J. Long. 94° 16½′ E. Lat. 13° 13½′ S.
K. Long. 104° 16½′ E. Lat. 6° 48½′ S.

26. **Composite Sailing** (Page 300).

(1) Initial course S. 61° 12′ 10″ W., final course N. 55° 30′ 29″ W., distance on first great circle 1358·25 miles, distance on second great circle 1725·42 miles, longitude where track meets the maximum latitude 111° 51′ 10″ W., longitude where track leaves the maximum latitude 145° 29′ 58″ W., distance along parallel of maximum latitude 1157·94 miles, total distance 4241·61 miles.

First point in long.	80° W.	is	31°	51′	10″	from vertex, and is in lat.	50° 29′ 58″	S.
Second point in long.	90° W.	is	21	51	10	from vertex, and is in lat.	52 58 7	S.
Third point in long.	100° W.	is	11	51	10	from vertex, and is in lat.	54 25 4	S.
Fourth point in long.	110° W.	is	1	51	10	from vertex, and is in lat.	54 59 9	S.

The points in longitudes 120°, 130° and 140° W. are on the parallel of maximum latitude.

Eighth point in long.	150° W.	is	4°	30′	2″	from vertex, and is in lat.	54° 55′ 0″	S.
Ninth point in long.	160° W.	is	14	30	2	from vertex, and is in lat.	54 7 26	S.
Tenth point in long.	170° W.	is	24	30	2	from vertex, and is in lat.	52 25 19	S.
Eleventh point in long.	180°	is	34	30	2	from vertex, and is in lat.	49 38 51	S.

(2) Initial course N. 60° 30′ 5″ E., final course S. 63° 29′ 42″ E., distance on first great circle 2067·22 miles, distance on second great circle 1794·8 miles, longitude in which the track meets maximum latitude 174° 51′ 51″ W., longitude in which the track leaves maximum latitude 161° 48′ 0″ W., distance along parallel of maximum latitude 554·27 miles, total distance 4416·29 miles.

First point in long.	150° E.	is	35°	8′	9″	from vertex, and is in lat.	39° 16′ 34″	N.
Second point in long.	160° E.	is	25	8	9	from vertex, and is in lat.	42 9 17	N.
Third point in long.	170° E.	is	15	8	9	from vertex, and in is lat.	43 59 20	N.
Fourth point in long.	180°	is	5	8	9	from vertex, and is in lat.	44 53 5	N.

The fifth point in long. 170° W. is on the parallel of maximum latitude.

Sixth point in long.	160° W.	is	1°	48′	0″	from vertex, and is in lat.	44° 59′ 9″	N.
Seventh point in long.	150° W.	is	11	48	0	from vertex, and is in lat.	44 23 17	N.
Eighth point in long.	140° W.	is	21	48	0	from vertex, and is in lat.	42 52 34	N.
Ninth point in long.	130° W.	is	31	48	0	from vertex, and is in lat.	40 21 39	N.

27. **Meridian Passage of Planet** (Page 305).

No.	Diff. in 1 day.	Corr. for longitude.	S.M.T.	G.M.T.
	min.	min.	d. h. m.	d. h. m.
1	3	+ 0·4	4 07 47·4	4 04 50·7
2	3	− 1·4	4 07 45·6	4 19 22·8
3	0	0	4 15 07	4 06 44
4	1	+ 0·3	4 15 07·3	4 23 30·3
5	5	+ 1·8	11 20 16·8	11 11 42·1
6	4	− 0·6	12 21 57·4	13 01 32·4

28. **Meridian Altitude of Planet** (Page 307).

No.	Diff. 1 day.	Corr. for long.	G.M.T.	Corr. decl.	Appx. obs. alt.	Latitude.
	min.	min.	d. h. m.	° ′	° ′	° ′
1	5	−2·3	14 08 46	26 39·4 N.	75 47·4 N.	
2	0	0	27 05 06	2 44·7 S.	30 59·9 S.	
3	—	0	3 07 50	21 16·9 N.		38 43·8 S.
4	4	0	24 19 47	22 15·6 S.		1 59·0 S.

29. **Longitude by Planet** (Page 309).

1. G.M.T. 2d. 20h. 20m. 00s., R. 06h. 47m. 55s., R.A. 21h. 54m. 25s., Decl. 14° 29·6′ S., *P Z* 44° 50′, *P X* 104° 29·6′, *Z X* (*p*) 79° 12·7′, hour angle 3h. 50m. 50s. W., longitude 20° 40′ W.

2. G.M.T. 10d. 22h. 28m. 40s., R. 07h. 19m. 48s., R.A. 05h. 27m. 51s., Decl. 26° 42·4′ N., *P Z* 35°, *P X* 63° 17·6′, *Z X* (*p*) 55° 08·7′, hour angle 4h. 26m. 28s. E., longitude 71° 46′ 15″ W.

3. G.M.T. 7d. 07h. 20m. 00s., R. 21h. 01m. 19s., R.A. 04h. 38m. 59s., Decl. 21° 22·3′ N., *P Z* 54° 58′, *P X* 111° 22·3′, *Z X* (*p*) 74° 03·3′, hour angle 3h. 22m. 26s. E., longitude 46° 11′ 30″ W.

30. **Planet Time Azimuth** (Page 312).

1. R. 06h. 53m. 18s., R.A. 22h. 00m. 29s., Decl. 13° 53·5′ S., S.M.T. 3d. 19h. 10m. 00s., R.A.M. 02h. 03m. 18s., hour angle 4h. 2m. 49s. W., true az. N. 120·1° W., error 14·9° E., dev. 1·6° E.

2. R. 21h. 01m. 19s., R.A. 04h. 38m. 58s., Decl. 21° 22·3′ N., S.M.T. 7d. 04h. 18m. 00s., R.A.M. 01h. 19m. 19s., hour-angle 3h. 19m. 39s. E., true az. S. 132° E., error 3° E., dev. 8° E.

3. G.A.T. 4d. 16h. 26m. 00s., E. 11h. 54m. 02s., S.M.T. 5d. 01h. 35m. 58s., G.M.T. 4d. 16h. 31m. 58s., R. 20h. 51m. 00s., R.A. 17h. 35m. 38s., Decl. 22° 13·3′ S., R.A.M. 22h. 26m. 58s., hour angle 4h. 51m. 20s. W., true az. S. 82·7° W., error 12·7° E., dev. 9·7° E.

31. **Planet Ex-meridian** (Page 315).

1. R. 20h. 54m. 23s., R.A. 04h. 37m. 45s., Decl. 21° 20·0′ N., S.M.T. 5d. 07h. 48m. 20s., R.A.M. 04h. 42m. 43s., hour angle 4m. 58s. W., *P Z* 54° 30′, *P X* 68° 40′, *Z X* (*p*) 56° 50·3′, mer. zen. dist. 56° 49·5′ S., latitude 35° 29·5′ S.

2. G.M.T. 5d. 11h. 40m. 00s., R. 20h. 54m. 09s., R.A. 17h. 35m. 31s., Decl. 22° 13·3′ S., R.A.M. 17h. 16m. 09s., hour angle 19m. 22s. E., *P Z* 59° 30′, *P X* 112° 13·3′, *Z X* (*p*) 52° 59·9′, mer. zen. dist. 52° 47·8′ N., latitude 30° 34·5′ N.

3. G.A.T. 10d. 11h. 32m. 00s., E. 11h. 52m. 27s., H.A.T.S. 10h. 12m. 0s., S.M.T. 10d. 22h. 19m. 33s., G.M.T. 10d. 11h. 39m. 33s., R. 07h. 18m. 02s., R.A. 05h. 28m. 18s., Decl. 26° 42·8′ N., R.A.M. 5h. 37m. 35s., hour angle 9m. 17s. W., mer. zen. dist. 66° 45′ S., latitude 40° 02·2′ S.

32. **Coal Consumption** (Page 329).

1. 7·7 tons for 12 knots.
2. 9·96 tons for 18 knots.
3. 3·16 tons for 8 knots.
4. 11·31 knots on 10 tons.
5. 81·85 revolutions on 14 tons.
6. She must steam at 8·05 knots.
7. She must steam at 10·04 knots.
8. She must steam at 12·15 knots.
9. She would burn 190·4 tons.
10. She must steam at 11·08 knots.
11. She could steam 1644 miles.
12. She must steam at 12·2 knots. Her reduction of speed must, therefore, be 2·8 knots.

Answers to Examination Paper I.

1. Star on the Meridian.

Approx. G.M.T. 14d. 22h. 03m. 53s., R. 13h. 30m. 20s., E. 11h. 59m. 44s.,
S.M.T. 20h. 34m. 16s., H.A.T.S. 8h. 34m. 0s., S.A.T. 20h. 34m. 00s., or 8h. 34m. P.M.

2. Stars near the Meridian.

E. 12h. 00m. 05s., R. 13h. 35m. 50s., H.A.T.S. 17h. 20m. 00s.,
S.M.T. 5h. 19m. 55s., R.A.M. 18h. 55m. 45s.

ε Sagittarii has crossed meridian South, hour angle, 0h. 36½m. W.
α Lyræ (*Vega*) ,, North, ,, 0h. 21m. W.
α Aquilæ (*Altair*) will cross meridian South, ,, 0h. 51½m. E.

3. Latitude by Star.

True alt. 78° 01·5′ S., Decl. 60° 02·0′ S., Lat. 48° 03·5′ S.

4. Compute Altitude of Star.

Appx. zen. dist. 37° 17·4′ S., appx. obs. alt. 52° 51·1′ N.

5. Longitude by Star.

G.M.T. 20d. 09h. 39m. 06s., R. 13h. 51m. 57·3s., PZ 53° 32′, PO 128° 42·6′, ZO (p) 78° 32·7, $PZ \sim PO$ 75° 10·6′, log hav. 8·65901, hour angle 1h. 38m. 39s. W., longitude 49° 28′ W.

6. Star Azimuth.

G.A.T. 13d. 15h. 57m. 20s., R. 13h. 25m. 24s., E. 11h. 59m. 25s.,
H.A.T.S. 10h. 48m. 0s., R.A.M. 12h. 13m. 59s., Hour angle 1h. 58m. 28s. E., true az. S. 149·2° E., error 23·2° W., dev. 4·7° W.

7. Sun Reduction.

S.M.T. 14d. 11h. 42m. 50s., E. 11h. 59m. 44s., H.A.T.S. 23h. 42m. 34s., P 17m. 26s., PX 80° 32·4′, obs. zen. dist. 29° 56·6′, mer. zen. dist. 29° 41·2′, lat. at obs. 39° 08·8′ N., lat. at noon 39° 07·6′ N.

8. Double Altitude (Sumner's Method).

First Observation.

G.M.T.,	. .	18d. 01h. 14m. 20s.
E.,	. . .	11h. 51m. 37s.
PZ,	. . .	39° 25′ and 40° 01′
PX,	. . .	91° 12·5′
ZX,	. . .	53° 36·8′ = p
A	Log. hav.,	8·29896
	Hour angle,	1h. 4m. 53s.
	Longitude,	147° 17′ 30″ E.
B	Log hav.,	8·41556
	Hour angle,	1h. 14m. 17s.
	Longitude,	144° 56′ 30″ E.

Second Observation.

G.M.T.,	. . .	18d. 05h. 36m. 16s.
E.,	. . .	11h. 51m. 40s.
PZ,	. . .	39° 25′ and 40° 01′
PY,	. . .	91° 08·2′
ZY,	. . .	66° 59·3′ = p
C	Log. hav.,	9·25536
	Hour angle,	3h. 20m. 51s.
	Longitude,	148° 13′ 45″ E.
D	Log hav.,	9·26516
	Hour angle,	3h. 23m. 18s.
	Longitude,	148° 50′ 30″ E.

Line of position, 1st obs., . . . N. 68° E. and S. 68° W.
Sun's true bearing, 2nd obs., . . S. 57° W.
Lat. 50° 8′ N., ... Long. 148° 42′ E.

9. Trigonometry.

Height of balloon, 7,496 feet.

11. Pole Star.

S.M.T. 14d. 05h. 20m. 28s., R. 13h. 27m. 19s., L.S.T. 18h. 47m. 47s., hour angle 6h. 47m. 8s. E., true alt. 33° 51·9′, corr. I. + 13·3′, corr. II. + ·4′, corr. III. — ·2′, latitude 34° 5·4′ N.

12. Meridian Altitude Moon.

Corr. for long. — 13′, S.M.T. 17d. 20h. 32m., G.M.T. 17d. 13h. 14·6m., semi-diameter 15·2′, hor. parallax 55′, parallax in altitude 33·4′, true alt. 53° 07·4′ N., latitude 48° 42·2′ S.

13. Napier's Diagram.

Magnetic bearing, N. 88° W.
Deviations, 8° E., 6° E., 4° E., 0, 4° W., 8° W., 6° W., 2° W.
Compass courses, N. 14° E., S. 5° E., N. 25° W., S. 29° W.
Magnetic courses, N. 73° E., N. 72° W., S. 60° W., S. 37° W.
Magnetic bearings, S. 70° E., S. 9° W.

14. Great Circle Sailing.

First course, S. 63° 36′ 58″ E. ; last course, N. 66° 20′ 2″ E. ; distance, 4,225·9 miles ; latitude of vertex, 39° 2′ 17″ S. ; longitude of vertex, 75° 55′ 27″ E.

Positions of points :—

C.	Long.	35° E.	Lat. 31° 29′ 42″ S.	H.	Long.	85° E.	Lat. 38° 41′ 7″ S.
D.	,,	45° E.	,, 34° 49′ 23″ S.	J.	,,	95° E.	,, 37° 27′ 54″ S.
E.	,,	55° E.	,, 37° 8′ 26″ S.	K.	,,	105° E.	,, 35° 19′ 30″ S.
F.	,,	65° E.	,, 38° 31′ 35″ S.	L.	,,	115° E.	,, 32° 11′ 25″ S.
G.	,,	75° E.	,, 39° 2′ 4″ S.				

Answers to Examination Paper II.

1. Star on the Meridian.

Approx. S.M.T. 11d. 22h. 59m. 17s., appx. G.M.T. 12d. 04h. 36m. 37s., R. corrected 15h. 17m. 52s., S.M.T. 22h. 54m. 41s., or 10h. 54m. 41s. P.M.

2. Meridian Altitude Star.

True alt. 78° 08·7′ S., Decl. 47° 18·2′ S., Lat. 35° 26·9′ S.

3. Compute Alt. of Star.

Decl. 8° 40·6′ N., appx. true alt. 45° 49·4′ N., appx. obs. alt. 45° 56·4′ N.

4. Stars near the Meridian.

G.M.T. 11d. 00h. 02m. 40s., R. 15h. 13m. 10s., R.A.M. 21h. 23m. 10s.

α Pavonis has crossed meridian S., hour angle, 1h. 3m. W.
α Gruis will cross meridian S., hour angle, 0h. 40½m. E.

5. Longitude by Star.

G.M.T. 12d. 07h. 24m. 19s., R. 15h. 18m. 19·3s., PZ 78° 22′, PO 70° 27′, ZO (p) 26° 44·8′, $PZ \sim PO$ 7° 55′, log hav. 8·72253, hour angle 1h. 46m. 16s. E., longitude 154° 6′ 45″ W.

6. Star Azimuth.

S.M.T. 12d. 05h. 46m. 00s., R. 15h. 17m. 52s., R.A.M. 21h. 03m. 52s., hour angle 1h. 16m. 32s. W., true az. S. 156° W., error 26° W., dev. 5° E.

7. Star Reduction.

G.M.T. 15d. 10h. 38m. 44s., S.M.T. 15d. 22h. 09m. 48s., R. 15h. 30m. 41s., R.A.M. 13h. 40m. 29s., hour angle 19m. 01s. W., obs. zen. dist. 49° 54·0′, mer. zen. dist. 49° 42·1′, latitude 38° 54·5′ N.

8. Double Altitude (Marcq St. Hilaire).

Ship's D.R. position at second obs., Lat. 52° 36′ N., Long. 5° 40·5′ W.

First Observation (the sun).—S.M.T. 15h. 59m. 14s., E. 12h. 08m. 57s., H.A.T.S. 4h. 8m. 11s., Decl. 01° 37′ S., PZ 37° 40′, PX 91° 37′, sun's true bearing N. 113° W., calculated alt. 15° 18·4′, true alt. 14° 59·9′, intercept away 18·5′.

Second Observation (Altair).—S.M.T. 18h. 19m. 05s., R. 00h. 24m. 15·5s., R.A.M. 18h. 43m. 20·5s., hour angle 1h. 4m. 0·5s. E., PZ 37° 24′, PY 81° 19·1′, star's true bearing N. 158° E., calculated alt. 44° 11·5′, true alt. 44° 18·4′, intercept towards 6·9′.

Line of position 2nd obs., N. 68° E. and S. 68° W.
Ship's position 2nd obs., lat. 52° 36½′ N., long. 5° 8′ W.

9. Trigonometry.

Course to steer, S. 88° 34½′ W.

10. Trigonometry.

$$\text{Sin } A = \frac{3}{\sqrt{58}}. \qquad \text{Cos } A = \frac{\sqrt{58}}{3}.$$

$$\text{Cos } A = \frac{7}{\sqrt{58}}. \qquad \text{Sec } A = \frac{\sqrt{58}}{7}.$$

$$\text{Tan } A = \frac{3}{7}. \qquad \text{Cot } A = \frac{7}{3}.$$

11. Pole Star.

G.M.T. 21d. 09h. 09m. 12s., R. 15h. 54m. 06s., L.S.T. 20h. 40m. 06s., hour angle 4h. 55m. 1s. E., true alt. 22° 34·1′, corr. I. − 17·6′, corr. II. + ·2′, corr. III. − ·4′, latitude 22° 16·3′ N.

12. Meridian Altitude Moon.

Corr. for long. + 5·2m., S.M.T. 17d. 17h. 21·2m., G.M.T. 17d. 19h. 59·4m., Decl. 3° 37·3′ N., semi-dia. 16·0′, hor. parallax 57·7′, parallax in alt. 27·3′, true alt. 62° 07·5′ S., latitude 31° 29·8′ N.

13. Napier's Diagram.

Magnetic bearing, S. 33° E.
Deviations, 16° E., 11° E., 3° E., 4° W., 11° W., 13° W., 7° W., 5° E.
Compass courses, N. 4° W., S. 46° E., S. 52° W., N. 21° W.
Magnetic courses, N. 46° E., S. 23° E., S. 86° W., N. 2° E.
Magnetic bearings, N. 27° E., N. 83° E.

14. Great Circle Sailing.

Initial course, S. 67° 11′ 22″ E.; final course, N. 47° 49′ 12″ E.; distance, 6,429·1 miles; latitude of vertex, 42° 37′ 15″ S.; longitude of vertex, 22° 38′ 37″ E.

Position of points :—

C.	Long.	10° W.	Lat. 37° 46′ 15″ S.	J.	Long.	50° E.	Lat. 39° 15′ 34″ S.
D.	,,	0°.	,, 40° 20′ 27″ S.	K.	,,	60° E.	,, 36° 11′ 2″ S.
E.	,,	10° E.	,, 41° 55′ 15″ S.	L.	,,	70° E.	,, 31° 56′ 20″ S.
F.	,,	20° E.	,, 42° 35′ 26″ S.	M.	,,	80° E.	,, 26° 23′ 55″ S.
G.	,,	30° E.	,, 42° 23′ 6″ S.	N.	,,	90° E.	,, 19° 30′ 30″ S.
H.	,,	40° E.	,, 41° 17′ 37″ S.	O.	,,	100° E.	,, 11° 23′ 18″ S.

Answers to Examination Paper III.

1. Star on the Meridian.

Appx. G.M.T. 21d. 17h. 12m. 20s., R. 17h. 57m. 38s., E. 11h. 58m. 28s., H.A.T.S. 16h. 54m. 35s., S.A.T. 22d. 04h. 54m. 35s.

2. Stars near the Meridian.

G.A.T. 25d. 07h. 32m. 40s., E. 11h. 57m. 42s., R. 18h. 11m. 49s., H.A.T.S. 16h. 58m. 00s., S.M.T. 05h. 00m. 48s., R.A.M. 23h. 12m. 07s.

β Gruis has crossed meridian South, hour angle 0h. 33½m. W.
Fomalhaut ,, South, ,, 0h. 18½m. W.
α Andromedæ will cross meridian North, hour angle 0h. 52½m. E.
α Phœnicis ,, South ,, 1h. 10½m. E.

3. Meridian Altitude Star.

True alt. 30° 37·5′ N., Decl. 28° 12·1′ N., Latitude 31° 10·4′ S.

4. Compute Altitude of Star.

Decl. 5° 24·5′ N., zen. dist. 36° 34·5′ S., appx. obs. mer. alt 53° 33·1′ N.

5. Longitude by Star.

G.M.T. 21d. 07h. 20m. 08s., R. 17h. 56m. 01s., PZ 35° 52°, PO 60° 00·3′, $PZ \sim PO$ 24° 08·3′, ZO (p) 51° 59·8′, log hav. 9·46616, hour angle 4h. 21m. 56s. E., longitude 101° 5′ W.

6. Star Azimuth.

G.A.T. 13d. 19h. 40m. 54s., R. 17h. 26m. 30s., E. 12h. 00m. 10s., H.A.T.S. 4h. 46m. 30s., R.A.M. 10h. 12m. 50s., hour angle 3h. 8m. 38s. E., true az. S. 116·3° E., error 6·3° W., dev. 6·3° W.

7. Sun Reduction.

S.M.T. 5d. 12h. 36m. 08s., E. 11h. 54m. 32s., H.A.T.S. 0h. 30m. 40s., decl. 22° 37·4′ S., *P Z* 53° 18′, *P O* 112° 37·4′, obs. zen. dist. 59° 48·8′, mer. zen. dist. 59° 22·5′ N., lat. at obs. 36° 45·1′ N., lat. noon 36° 40·5′ N.

8 Double Altitude (Sumner's method)

First Observation.		Second Observation.	
G.M.T.,	20d. 16h. 46m. 11s.	G.M.T.,	20d. 20h. 25m. 23s.
E.,	12h. 01m. 05s.	E.,	12h. 01m. 07s.
P Z,	40° 10′ and 39° 50′	*P Z*,	40° 10′ and 39° 50′
P X,	78° 29·1′	*P Y*,	78° 26·1′
Z X,	43° 29·7′ = *p*	*Z Y*,	75° 06·4′ = *p*
A Log. hav.,	8·67032	C Log. hav.,	9·62102
A Hour angle,	1h. 39m. 58s.	C Hour angle,	5h. 22m. 10s.
A Longitude,	46° 49′ 30″ W.	C Longitude,	46° 5′ W.
B Log. hav.,	8·64584	D Log. hav.,	9·62105
B Hour angle,	1h. 37m. 8s.	D Hour angle,	5h. 22m. 11s.
B Longitude,	47° 32′ W.	D Longitude,	46° 4′ 45″ W.

Line of position, 1st obs., . . . N. 54° W. and S. 54° E.
Sun's true bearing, 1st obs., . . . S. 36° W.
Lat. 49° 55′ N., ... Long. 46° 4′ 45″ W.

9. Trigonometry.

Angle to which sextant must be set, 11° 37′

11. Pole Star.

G.A.T. 28d. 05h. 00m. 52s., E. 11h. 57m. 06s., S.M.T. 20h. 48m. 54s., G.M.T. 28d. 05h. 03m. 46s., R. 18h. 23m. 15s., L.S.T. 15h. 12m. 9s., hour angle 10h. 23m. 25s. E., true alt. 18° 45·6′, corr. I. + 58·5′, corr. II. 0, corr. III. + ·7′, latitude 19° 44·8′ N.

12. Meridian Altitude Moon.

Corr. for long. + 24m., S.M.T. 19d. 19h. 17m., G.M.T. 20d. 05h. 47·1m., semi-dia. 16·4′, hor. parallax 59·4′, parallax in alt. 26·8′, decl. 17° 11·6′ N., true alt. 63° 38·6′, latitude 9° 9·8′ S.

13. Napier's Diagram.

Magnetic bearing, S. 77° W.
Deviations, 6° W., 4° E., 11° E., 15° E., 7° E., 1° W., 13° W., 19° W.
Compass courses, N. 20° E., N. 87° E., S. 22° E., N. 79° W.
Magnetic courses, N. 41° E., S. 2° E., S. 66° W., N. 31° W.
Magnetic bearings, S. 77° W., S. 24° E.

14. Great Circle Sailing.

Initial course, S. 35° 51′ E. ; final course, N. 35° 27′ E. : distance, 6,108 miles ; lat. of vertex, 60° 54′ S. ; long. of vertex, 140° 40′ W.

Position of points :—

C. Long. 159° 20′ E.	Lat. 41° 56′ S.	F. Long. 170 40′ W.	Lat. 57° 16′ S.
D. ,, 169° 20′ E.	,, 49° 7′ S.	G. ,, 160° 40′ W.	,, 59° 22′ S.
E. ,, 179° 20′ E.	,, 54° 0′ S.	H. ,, 150° 40′ W.	,, 60° 32′ S.

There are also six points on the other side of the vertex ; their polar angles (longitude from vertex) being the same as the above, they must also be in respectively the same latitudes.

Answers to Examination Paper IV.

1. Star on the Meridian.

Approx. S.M.T. 8d. 07h. 27m. 49s., approx. G.M.T. 8d. 08h. 59m. 49s., R. 21h. 05m. 32s., E. 11h. 54m. 25s., H.A.T.S. 19h. 20m. 45s., S.A.T. 7h. 20m. 45s.

2. Meridian Altitude Star.

True altitude 60° 17·6′ N., latitude 48° 04·6′ S.

3. Compute Altitude of Star.

Approx. zen. dist. 7° 45·4′ N., approx. obs. mer. alt. 82° 17·1′ S.

4. Stars near the Meridian.

G.A.T. 3d. 14h. 05m. 40s., H.A.T.S. 15h. 31m. 0s., E. 11h. 53m. 57s., G.M.T. 3d. 14h. 11m. 43s., R. 20h. 46m. 41s., R.A.M. 0h. 23m. 45s.

Fomalhaut has crossed meridian N., hour angle 1h. 30m. W.
Achernar will cross meridian S., hour angle 1h. 11m. E.

5. Longitude by Star.

G.M.T. 2d. 19h. 36m. 18s., R. 20h. 43m. 37s., PZ 74° 14′, PO 128° 43·1′, ZO (p) 67° 24·9′, $PZ \sim PO$ 54° 29·1′, log hav. 9·11756, hour angle 2h. 49m. 49s. W., longitude 76° 7′ E.

6. Star Time Azimuth.

S.M.T. 3d. 02h. 38m. 00s., R. 20h. 46m. 23s., R.A.M. 23h. 24m. 23s., hour angle 5h. 7m. 29s. E., true az. N. 87·2° E., error 10·2° E., dev. 9·8° W.

7. Star Reduction.

S.M.T. 1d. 01h. 48m. 29s., R. 20h. 37m. 01s., R.A.M. 22h. 25m. 30s., hour angle 28m. 17s. E., obs. zen. dist. 74° 23·8′, mer. zen. dist. 74° 06·9′, latitude 44° 07·2′ N.

8. Double Altitude (Marcq St. Hilaire).

Ship's position by D.R. at second obs. :—Lat. 41° 5′ N., Long. 45° 47′ W.

First Observation (*the sun*).—S.M.T. 1d. 15h. 01m. 40s., E. 11h. 53m. 49s., H.A.T.S. 2h. 55m. 29s., PZ 49° 0′, PO 71° 58·6′, sun's true bearing by azimuth tables N. 108° W., calculated alt. 46° 05′, true alt. 45° 59′, intercept away 6′.

Second Observation (*Saturn*).—S.M.T. 1d. 19h. 07m. 11s., R. 20h. 40m. 06s., planet's R.A. 17h. 36m. 07s., planet's decl. 22° 13·1′ S., planet's hour angle 1h. 48m. 50s. E., true bearing by azimuth tables N. 153° E., calculated alt. 21° 50·7′, true alt. 21° 53·7′, intercept towards 3′.

Ship's position at second obs. :—Lat. 41° 04′ N., Long. 45° 38′ W.

9. Trigonometry.

Distance between the two vessels, 12·22 miles.

11. Pole Star.

S.M.T. 7d. 04h. 48m. 00s., R. 20h. 59m. 32s., L.S.T. 1h. 47m. 32s., hour angle 0h. 10m. 48s. W., true alt. 27° 45′, corr. I. — 1° 3·9′, corr. II. 0, corr. III. — ·8′, latitude 26° 40·3′ N.

12. Meridian Altitude Moon.

Corr. for long. — 8·3m., S.M.T. 19d. 18h. 44·7m., G.M.T. 19d. 14h. 44·7m., decl. 13° 55·6′ N., semi-dia. 16·3′, hor. parallax 59·0′, parallax in alt. 26·2′, true alt. 64° 04·2′, latitude 12° 0·2′ S.

13. Napier's Diagram.

Magnetic bearing, S. 13° E.
Deviations, 22° E., 12° E., 7° W., 22° W., 26° W., 23° W., 9° E., 32° E.
Compass courses required, N. 17° W., S. 82° E., S. 16° W., N. 78° W.
Magnetic courses required, N. 48° E., N. 85° E., S. 24° E., N. 15° E.
Magnetic bearings, N. 12° W., S. 26° E.

14. Great Circle Sailing.

Initial course, N. 77° 24′ 27″ W. ; final course, S. 53° 25′ 13″ W. ; latitude of vertex, 52° 30′ 29″ N. ; longitude of vertex, 25° 25′ 55″ W. ; distance, 2,674 miles.

Position of points :—

C.	Latitude, 52° 5′ 1″ N.	Longitude, 15° 25′ 55″ W.
D.	,, 52° 5′ 1″ N.	,, 35° 25′ 55″ W.
E.	,, 50° 46′ 27″ N.	,, 45° 25′ 55″ W.
F.	,, 48° 27′ 59″ N.	,, 55° 25′ 55″ W.
G.	,, 44° 57′ 38″ N.	,, 65° 25′ 55″ W.

Answers to Examination Paper V.

1. Meridian Altitude Star.

True altitude 40° 12·0′ N., latitude 22° 51′ S.

2. Compute Altitude of Star.

Approx. zen. dist. 42° 29′ S., approx. true alt. 47° 31′ N., approx. obs. mer. alt. 47 36·8′ N.

3. Longitude by Star.

G.M.T. 23d. 13h. 01m. 21s., R. 12h. 02m. 07s., PZ 80° 19′, PO 102° 18·9′, ZO (p) 50° 21·6′, log hav. 9·17656, hour angle 3h. 2m. 24s. W., longitude 179° 6′ 45″ W.

4. Stars near the Meridian.

S.M.T. 29d. 23h. 19m. 40s., R. 06h. 30m. 42s., R.A.M. 5h. 50m. 22s.

α Orionis (*Betelguese*)	will cross meridian	North, hour angle,	0h. 1m. E.
α Argus (*Canopus*)	,,	South, ,,	0h. 32m. E.
α Can. Maj. (*Sirius*)	,,	North, ,,	0h. 52m. E.

5. Star Azimuth.

S.M.T. 28d. 02h. 22m. 28s., R. 06h. 22m. 40s., R.A.M. 08h. 45m. 08s., hour angle 2h. 3m. 4s. W., true az. N. 143·6° W., error 6·4° E., dev. 6·4° E.

6. Sun Reduction.

S.M.T. 20d. 12h. 18m. 12s., E. 12h. 03m. 40s., H.A.T.S. 0h. 21m. 52s., decl. 19° 50·9′ N., obs. zen. dist. 61° 34·0′, mer. zen. dist. 61° 21·5′, lat. obs. 41° 30·6′ S., lat noon 41° 29·2′ S.

7. Star on the Meridian.

Approx. S.M.T. 15d. 02h. 54m. 25s., approx. G.M.T. 15d. 01h. 34m. 25s., S.M.T. 15d. 02h. 54m. 09s.

8. Double Altitude (Sumner's method).

First Observation.		Second Observation.	
G.M.T.,	9d. 12h. 37m. 09s.	G.M.T.,	9d. 16h. 15m. 06s.
E.,	11h. 52m. 51s.	E.,	11h. 52m. 47s.
P Z,	38° 30′ and 38° 39·8′	*P Z*,	38° 30′ and 38° 39·8′
P X,	112° 07·9′	*P Y*,	112° 6·6′
Z X,	76° 28·3′	*Z Y*,	78° 25·9′
A Log. hav.,	8·61833	C Log hav.,	8·84989
A Hour angle,	1h. 34m. 4s.	C Hour angle,	2h. 3m. 26s.
A Longitude,	31° 01′ W.	C Longitude,	31° 6′ 45″ W.
B Log hav.,	8·64083	D Log hav.,	8·86261
B Hour angle,	1h. 36m. 34s.	D Hour angle,	2h. 5m. 18s.
B Longitude,	31° 38′ 30″ W.	D Longitude,	30° 38′ 45″ W.

Line of position, 1st obs., . . . N. 68° E. and S. 68° W.
Sun's true bearing, 1st obs., . . . S. 22° E.
Lat. 51° 14′ N., ... Long. 30° 22′ W.

9. Trigonometry.

Course she will have to steer, N. 15° 14½′ W.

11. Latitude by Pole Star.

G.M.T. 7d. 16h. 40m. 52s., S.M.T. 8d. 03h. 40m. 00s., R. 21h. 02m. 51s., L.S.T. 0h 42m. 51s., hour angle 0h. 53m. 53s. E., true alt. 31° 0·4′, corr. I. — 1° 02·3′ corr. II. 0, corr. III. — ·6′, latitude 29° 57·5′ N.

12. Meridian Altitude Moon.

Corr. for long. + 18m., S.M.T. 26d. 01h. 53m., G.M.T. 26d. 10h. 42m., decl. 22° 9·9′ S., semi-dia. 15·1′, hor. parallax 54·4′, parallax in alt. 21·7′, true alt. 66° 52·0′ N., latitude 45° 17·9′ S.

13. Napier's Diagram.

Magnetic bearing, S. 76° W.
Deviations, 14° W., 0, 12° E., 15° E., 11° E., 0, 10° W., 14° W.
Compass courses required :—N. 19° E., N. 78° E., S. 34° W., N. 8° W.
Magnetic courses required, N. 45° E., S. 67° E., S. 26° W., N. 62° W.
Magnetic bearings, N. 33° E., S. 65° E.

14. Great Circle Sailing.

Initial course, N. 68° 31′ 47″ W.; final course, S. 67° 19′ 25″ W.; distance, 3,324·5 miles; latitude of vertex, 41° 6′ 17″ N.; longitude of vertex, 39° 25′ 50″ W.

Position of points :—

C.	Longitude, 10° W.	Latitude, 37° 13′ 53″ N.
D.	,, 20° W.	,, 39° 26′ 52″ N.
E.	,, 30° W.	,, 40° 43′ 8″ N.
F.	,, 40° W.	,, 41° 6′ 12″ N.
G.	,, 50° W.	,, 40° 37′ 10″ N.
H.	,, 60° W.	,, 39° 14′ 40″ N.
J.	,, 70° W.	,, 36° 54′ 55″ N.

Answers to Examination Paper VI.

1. Meridian Altitude Star.

Polar dist. 27° 51·7′, true alt. 18° 29·6′ N., latitude 46° 21·3′ N.

2. Compute Altitude of Star.

Approx. zen. dist. 37° 15·1′, approx. true alt. 52° 44·9′, approx. obs. alt. 52° 49·8′.

3. Longitude by Star.

G.M.T. 21d. 01h. 00m. 45s., R. 15h. 52m. 45s., PZ 40° 54′, PO 81° 19·4′, ZO (p) 78° 39·7′, log hav. 9·63970, hour angle 5h. 30m. 41s. E., longitude 39° 12′ 45″ W.

4. Stars near the Meridian.

G.A.T. 19d. 04h. 56m. 00s., E. 11h. 59m. 01s., G.M.T. 19d. 04h. 56m. 59s., R. 17h. 47m. 44s., R.A.M. 21h. 56m. 43s.

α Pavonis	has crossed meridian	South,	hour angle, 1h. 37m. W.
α Cygni	,,	North,	,, 1h. 18m. W.
α Gruis	will cross meridian	South,	,, 0h. 7m. E.
β Gruis	,,	South,	,, 0h. 42m. E.
Fomalhaut	,,	South,	,, 0h. 57m. E.

5. Star Time Azimuth.

G.A.T. 27d. 13h. 22m. 00s., E. 11h. 57m. 14s., G.M.T. 27d. 13h. 24m. 46s., R. 18h. 20m. 40s., R.A.M. 22h. 18m. 26s., hour angle 2h. 31m. 5s. W., true az. S. 135·3° W., error 6·3° E., dev. 6·7° W.

6. Star Reduction.

G.A.T. 24d. 05h. 39m. 50s., E. 12h. 00m. 36s., G.M.T. 24d. 05h. 39m. 14s., R. 06h. 09m. 04s., R.A.M. 06h. 32m. 18s., hour angle 9m. 46s. E., obs. zen. dist. 29° 41·6′, mer. zen. dist. 29° 37·5′, latitude 46° 14·5′ S.

7. Star on the Meridian.

Approx. G.M.T. 13d. 20h. 45m. 49s., R. 13h. 26m. 11s., S.M.T. 05h. 08m. 21s., E. 11h. 59m. 28s., H.A.T.S. 17h. 7m. 49s., S.A.T. 14d. 05h. 07m. 49s.

8. Double Altitude (Marcq St. Hilaire).

Ship's position by D.R. at second observation, lat. 50° 51·2′ N. ; longitude 7° 16·5′ W.

First Observation (*the sun*).—G.M.T. 25d. 11h. 02m. 04s., E. 11h. 59m. 59s., H.A.T.S. 22h. 30m. 43s., *P* 1h. 29m. 17s., *P Z* 39° 30′, *P O* 113° 24·6′, sun's true bearing N. 159° E., calculated alt. 13° 29·8′, true alt. 13° 22·4′, intercept away 7·4′.

Second Observation (*the sun*).—G.M.T. 25d. 14h. 31m. 58s., E. 11h. 59m. 55s., H.A.T.S. 2h. 2m. 47s. = *P*, *P Z* 39° 08·8′, *P Y* 113° 24·5′, sun's true bearing N. 151° W., calculated alt. 10° 57·5′, true alt. 10° 43·0′, intercept away 14·5′.

Ship's position at second obs., lat. 51° 3′ N., longitude 7° 2′ W.

9. Trigonometry.

The sun will set at 7h. 35m. 22s. P.M. appt. time (19h. 35m. 22s.).

11. Latitude by Pole Star.

G.A.T. 25d. 21h. 49m. 00s., E. 11h. 57m. 35s., G.M.T. 25d. 21h. 51m. 25s., R. 18h. 14m. 10s., L.S.T. 16h. 16m. 35s., hour angle 9h. 18m. 59s. E., true alt. 39° 55·4′, corr. I. + 49·0′, corr. II. + 0·2′, corr. III. + 0·6′, latitude 40° 45·2′ N.

12. Meridian Altitude Moon.

Corr. for long. — 14·5, S.M.T. 26d. 01h. 20·5m., G.M.T., 25d. 17h. 45·3m., decl. 19° 35·7′ S., semi-dia. 15·1′, hor. parallax 54·7′, parallax in alt. 32·9′, true alt. 53° 33·2′, latitude 16° 51·1′ N.

13. Napier's Diagram.

Magnetic bearing, North.
Deviations, 3° W., 6° E., 10° E., 14° E., 3° E., 6° W., 10° W., 14° W.
Compass courses, N. 17° E., S. 40° E., S. 60° W., North.
Magnetic courses, N. 87° E., S. 29° E., S. 46° W., S. 83° E.
Magnetic bearings, S. 70° E., N. 9° E.

14. Great Circle Sailing.

Initial course, N. 55° 34′ E. ; final course, N. 59° 57′ E. ; distance, 6,417 miles ; lat. of vertex, 46° 46½′ N. ; long. of vertex, 79° 35½′ W.

Position of points :—

C.	Long. 160° E.	Lat. 28° 18′ S.		G.	Long. 160° W.	Lat. 10° 3′ N.
D.	,, 170° E.	,, 20° 21½′ S.		H.	,, 150° W.	,, 19° 38′ N.
E.	,, 180°.	,, 10° 53′ S.		J.	,, 140° W.	,, 27° 43′ N.
F.	,, 170° W.	,, 0° 26′ S.		K.	,, 130° W.	,, 34° 8′ N.

Answers to Examination Paper VII.

1. Meridian Altitude Star.

True alt. 19° 47·7′ N., Polar dist. 27° 51·7′, latitude 47° 39·4′ N.

2. Compute Altitude of Star.

Polar dist. 37° 20·4′, approx. true alt. 15° 07·6′, approx. obs. alt. 15° 19·3′.

3. Longitude by Star.

G.M.T. 23d. 14h. 51m. 18s., 66·1 days, acc. rate 1m. 59s. to add, R. 06h. 06m. 38s., PZ 71° 24′, PX 106° 37′, ZX (p) 47° 23·5′, $PZ \sim PX$ 35° 13′, log hav. 8·88693, hour angle 2h. 8m. 57s. E., longitude 113° 47′ 45″ E.

4. Stars near the Meridian.

G.A.T. 23d. 03h. 24m. 00s., E. 12h. 01m. 08s., H.A.T.S. 15h. 46m. 0s., S.M.T. 03h. 44m. 52s., G.M.T. 23d. 03h. 22m. 52s., R. 06h. 04m. 45s., R.A.M. 9h. 49m. 37s.

α Leonis will cross meridian South, hour angle, 0h. 15m. E.

5. Star Azimuth.

G.A.T. 24d. 08h. 08m. 58s., E. 12h. 00m. 33s., H.A.T.S. 6h. 2m. 10s., S.M.T. 18h. 01m. 37s., G.M.T. 24d. 08h. 08m. 25s., R. 06h. 09m. 28s., R.A.M. 0h. 11m. 5s., hour angle 4h. 20m. 49s. E., true az. N. 99·6° E., error 1·1° E., dev. 7·6° E.

6. Sun Reduction.

G.A.T. 13d. 18h. 02m. 05s., E. 12h. 00m. 11s., H.A.T.S. 0h. 45m. 1s.= P, S.M.T. 12h. 44m. 50s., G.M.T. 13d. 18h. 01m. 54s., PZ 38° 32′, PX 113° 13·2′, obs. zen. dist. 75° 18·9′, mer. zen. dist. 74° 39·7′, nat. hav. 0·36775, lat. at obs. 51° 26·5′ S., lat. at noon 51° 37·1′ S.

7. Star on the Meridian.

Approx. S.M.T. 20d. 22h. 23m. 48s., approx. G.M.T. 21d. 04h. 03m. 48s., R. 15h. 53m. 15s., S.M.T. 22h. 19m. 12s., E. 12h. 03m. 37s., H.A.T.S. 10h. 22m. 49s., S.A.T. 22h. 22m. 49s., or 10h. 22m. 49s. P.M.

By inspection, 22h. 24m., apparent time.

8. Double Altitude (Sumner's method).

Run S. 78° W.	Lat. 1st obs.	46°	50′ N.	.....co-lat. 43°	10′ $=PZ$
32 miles	D. lat.		6·7 S.		
D. lat. 6·7 S.	Lat. 2nd. obs.	46	43·3 N.	.....co-lat. 43	16·7$=PZ$

First Observation.

G.M.T.,		10d. 23h. 24m. 21s.
PX,		111° 55·2′
$ZX(p)$,		76 22·9
E.,		11h. 52m. 15s.
A	Hour angle,	2h. 27m. 29s.
	Longitude,	153° 58′ 45″ E.
B	Hour angle,	2h. 28m. 24s.
	Longitude,	153° 45′ E.

Second Observation.

G.M.T.,		11d. 2h. 42m. 7s.
PY,		111° 53·9′
$ZY(p)$,		69 19·5
E.,		11h. 52m. 12s.
C	Hour angle,	0h. 40m. 3s.
	Longitude,	151° 26′ 0″ E.
D	Hour angle,	0h. 43m. 40s.
	Longitude,	152° 20′ 15″ E.

Line of position, 1st obs.	N. 55° E. and S. 55° W.
Sun's true bearing, 1st obs.,	S. 35° E.
Lat. 46° 38′ N.	Long. 153° 3′ E.

The same problem worked by Marcq St. Hilaire.

First Observation.—Lat. by D.R., 46° 50′ N.; long. by D.R., 153° 30′ E.; G.M.T., 10d. 23h. 24m. 21s., E. 11h. 52m. 15s., H.A.T.S. 21h. 30m. 36s., *P* 2h. 29m. 24s., *P Z* 43° 10′, *P X* 111° 55·2′, sun's true bearing N. 145° E., calculated alt. 13° 25·8′, true alt. 13° 37·1′, intercept towards 11·3′.

Second Observation.—Lat. by D.R. 46° 43·3′ N., Long. by D.R. 152° 44·3′ E., G.M.T. 11d. 02h. 42m. 07s., E. 11h. 52m. 12s., H.A.T.S. 0h. 45m. 16s. = *P*, *P Z* 43° 16·7′, *P Y* 111° 53·9′, sun's true bearing N. 169° W., calculated alt. 20° 37·3′, true alt. 20° 40·5′, intercept towards 3·2′.

Line of position 1st obs., N. 55° E. and S. 55° W.
Sun's true bearing 1st obs., S. 35° E.
Ship's position 2nd obs., lat. 46° 38′ N., long. 153° 3′ E.

9. Trigonometry.

Course and distance made good, N. 41° 24′ W. 10·47 miles.

12. Pole Star.

S.M.T. 21d. 03h. 03m. 10s., R. 11h. 54m. 08s., L.S.T. 14h. 57m. 18s., hour angle 10h. 37m. 44s. E., true alt. 49° 24·7′, corr. I. + 1° 0′, corr. II. + 0·1′, corr. III. + 0·4′, latitude 50° 25·2′ N.

13. Meridian Altitude Moon.

Corr. for long. — 7·4m., S.M.T. 19d. 22h. 07·6m., G.M.T. 19d. 18h. 16·6m., decl. 21° 26·0′ S., semi-dia. 15·0′, hor. parallax 54·3′, parallax in alt. 17·8′, true alt. 71° 10·6′, latitude 2° 36·6′ S.

14. Napier's Diagram.

Magnetic bearing, N. 50° W.
Deviations, 16° W., 3° W., 14° E., 23° E., 16° E., 1° W., 14° W., 19° W.
Compass courses, N. 30° E., S. 73° E., S. 78° W., N. 38° W.

15. Great Circle Sailing.

Initial course, S. 78° 35′ 10″ E.; distance, 4228·6 miles; lat. of vertex, 35° 48′ 7″ S.; long. of vertex, 45° 28′ 22″ E.

Position of points :—

A. Long. 40° E. Lat. 35° 40′ 40″ S.
B. Long. 60° E. Lat. 34° 55′ 24″ S.
C. Long. 80° E. Lat. 30° 43′ 12″ S.
D. Long. 100° E. Lat. 22° 42′ 45″ S.

The course and distance from one point to another may be found by taking it off with the parallel rules and compasses, after having first plotted off the positions of the points on the chart.

It may also be found by calculation on Mercator's principle, or by middle latitude sailing when the course is near East or West.

16. Trigonometry.

Distance from *B* at second observation 2·406 miles.

JANUARY, 1929.

Star's Name.	Mag.	Right Ascension.	Declination.
		h. m. s.	° ′
α Andromedæ, ... *Alpheratz*	2·2	00 04 41	N. 28 41·9
α Phœnicis, ...	2·4	00 22 46	S. 42 41·8
α Cassiopeiæ, . . . *Schedar*	2·1-2·6	00 36 26	N. 56 09·1
β Ceti, ...	2·2	00 40 01	S. 18 22·8
β Andromedæ, ...	2·4	01 05 44	N. 35 14·8
α Ursæ Minoris . . . *Polaris*	2·1	01 35 57	N. 88 55·7
α Eridani . . . . *Achernar*	0·6	01 35 04	S. 57 36·2
γ Andromedæ, ...	2·2	01 59 31	N. 41 59·5
α Arietis, ... *Hamal*	2·2	02 03 09	N. 23 07·7
α Persei, ... *Mirfak*	1·9	03 19 14	N. 49 36·8
α Tauri, ... *Aldebaran*	1·1	04 31 51	N. 16 22·1
β Orionis, ... *Rigel*	0·3	05 11 08	S. 8 17·0
α Aurigæ, ... *Capella*	0·2	05 11 27	N. 45 55·8
γ Orionis, ... *Bellatrix*	1·7	05 21 20	N. 6 17·2
β Tauri, ... *Nath*	1·8	05 21 48	N. 28 33·0
ε Orionis, ...	1·8	05 32 37	S. 1 14·7
ζ Orionis, ...	1·9	05 37 11	S. 1 58·7
α Orionis, ... *Betelguese*	0·5-1·1	05 51 20	N. 7 23·8
β Aurigæ, ...	2·1	05 54 20	N. 44 56·7
β Canis Majoris, . . . *Mirzam*	2·0	06 19 35	S. 17 55·2
α Argus, ... *Canopus*	−0·9	06 22 24	S. 52 39·4
γ Geminorum, ... *Alhena*	1·9	06 33 37	N. 16 27·7
α Canis Majoris, ... *Sirius*	−1·6	06 42 02	S. 16 37·1
ε Canis Majoris, ...	1·6	06 55 51	S. 28 52·4
δ Canis Majoris, ...	2·0	07 05 31	S. 26 16·7
α Geminorum, ... *Castor*	1·6	07 30 05	N. 32 02·8
α Canis Minoris, . . . *Procyon*	0·5	07 35 36	N. 5 24·5
β Geminorum, ... *Pollux*	1·2	07 40 59	N. 28 12·0
γ Argus, ...	1·9	08 07 22	S. 47 07·5
ε Argus, ...	1·7	08 21 05	S. 59 16·7
δ Argus, ...	2·0	08 42 46	S. 54 26·7
β Argus, ...	1·8	09 12 28	S. 69 25·3
α Hydræ, ... *Alphard*	2·2	09 24 06	S. 8 20·9
α Leonis, ... *Regulus*	1·3	10 04 36	N. 12 18·9
γ Leonis, ...	2·3	10 16 04	N. 20 12·0
β Ursæ Majoris, ...	2·4	10 57 35	N. 56 45·7
α Ursæ Majoris, ... *Dubhe*	2·0	10 59 23	N. 62 07·9
β Leonis, ... *Denebola*	2·2	11 45 26	N. 14 58·1
α Crucis, ...	1·1	12 22 38	S. 62 42·0
γ Crucis, ...	1·6	12 27 12	S. 56 42·6
β Crucis, ...	1·5	12 43 33	S. 59 17·7
ε Ursæ Majoris, ... *Alioth*	1·7	12 50 55	N. 56 20·5
ζ Ursæ Majoris, ... *Mizar*	2·2	13 21 04	N. 55 17·5
α Virginis, ... *Spica*	1·2	13 21 26	S. 10 47·4
η Ursæ Majoris, ... *Benetnasch*	1·9	13 44 44	N. 49 39·8
β Centauri, ...	0·9	13 58 46	S. 60 01·6
α Bootis, ... *Arcturus*	0·2	14 12 25	N. 19 32·9
α Centauri, ...	0·1	14 34 44	S. 60 32·3
β Ursæ Minoris, ... *Kochab*	2·2	14 50 53	N. 74 26·4
α Coronæ Borealis, . . . *Alphacca*	2·3	15 31 40	N. 26 57·0
α Scorpii, ... *Antares*	1·2	16 25 01	S. 26 16·5
α Trianguli Australis, ...	1·9	16 41 03	S. 68 53·8
α Ophiuchi, ...	2·1	17 31 36	N. 12 36·5
α Lyræ, ... *Vega*	0·1	18 34 30	N. 38 42·8
α Pavonis, ...	2·1	20 19 59	S. 56 58·0
α Cygni, ... *Deneb*	1·3	20 38 58	N. 45 01·5
α Gruis, ...	2·2	22 03 44	S. 47 18·6
β Gruis, ...	2·2	22 38 24	S. 47 15·7
α Piscis Australis, . . *Fomalhaut*	1·3	22 53 42	S. 30 00·2

JANUARY, 1929.

Date.		Day of Year.	Sun's Semi-diameter.	THE MOON'S								Age at 0h.
				Semi-diameter.	Horizontal Parallax.	Meridian Passage.						
						Upper.		Diff.	Lower.		Diff.	
			′	′	′	h.	m.	m.	h.	m.	m.	d.
Tues.	1	1	16·3	15·6	57·2	04	56	44	17	18	43	19·8
Wed.	2	2	16·3	15·3	56·3	05	40	42	18	01	42	20·8
Thur.	3	3	16·3	15·1	55·5	06	22	41	18	43	41	21·8
Fri.	4	4	16·3	15·0	54·9	07	03	42	19	24	43	22·8
Sat.	5	5	16·3	14·8	54·5	07	45	44	20	07	45	23·8
Sun.	6	6	16·3	14·8	54·2	08	29	46	20	52	46	24·8
Mon.	7	7	16·3	14·7	54·0	09	15	48	21	38	49	25·8
Tues.	8	8	16·3	14·7	54·0	10	03	50	22	27	51	26·8
Wed.	9	9	16·3	14·7	54·1	10	53	51	23	18	52	27·8
Thur.	10	10	16·3	14·8	54·3	11	44	51	*	*		28·8
Fri.	11	11	16·3	14·9	54·6	12	35	51	00	10	51	29·8
Sat.	12	12	16·3	15·0	54·9	13	26	48	01	01	49	1·0
Sun.	13	13	16·3	15·1	55·3	14	14	47	01	50	48	2·0
Mon.	14	14	16·3	15·2	55·7	15	01	45	02	38	46	3·0
Tues.	15	15	16·3	15·3	56·2	15	46	45	03	24	45	4·0
Wed.	16	16	16·3	15·5	56·8	16	31	45	04	09	45	5·0
Thur.	17	17	16·3	15·6	57·4	17	16	47	04	54	45	6·0
Fri.	18	18	16·3	15·8	58·0	18	03	50	05	39	49	7·0
Sat.	19	19	16·3	16·0	58·7	18	53	55	06	28	52	8·0
Sun.	20	20	16·3	16·2	59·3	19	48	59	07	20	57	9·0
Mon.	21	21	16·3	16·3	59·9	20	47	63	08	17	61	10·0
Tues.	22	22	16·3	16·4	60·4	21	50	65	09	18	65	11·0
Wed.	23	23	16·3	16·5	60·6	22	55	65	10	23	65	12·0
Thur.	24	24	16·3	16·5	60 6	00	00	60	11	28	62	13·0
Fri.	25	25	16·3	16·4	60 3	*	*		12	30	58	14·0
Sat.	26	26	16·3	16·3	59·8	01	00	55	13	28	53	15·0
Sun.	27	27	16·3	16·1	59·1	01	55	50	14	21	48	16·0
Mon.	28	28	16·3	15·9	58·2	02	45	47	15	09	45	17·0
Tues.	29	29	16·3	15·6	57·3	03	32	44	15	54	43	18·0
Wed.	30	30	16·3	15·4	56·5	04	16	42	16	37	43	19·0
Thur.	31	31	16·3	15·2	55·7	04	58	43	17	20	43	20·0
Fri.	32	32	16·3	15·0	55·1	05	41		18	03		21·0

JANUARY. 1929.

THE SUN.

G.M.T.	Wednesday 2									Monday 7								
	R.			Dec.			*E.*			*R.*			Dec.			*E.*		
h.	h.	m.	s.	°	′		h.	m.	s.	h.	m.	s.	°	′		h.	m.	s.
00	06	44	34·2	S. 22	59·0		11	56	12·2	07	04	17·0	S. 22	27·9		11	53	55·6
02	06	44	53·9	22	58·6		11	56	09·9	07	04	36·7	22	27·3		11	53	53·4
04	06	45	13·6	22	58·2		11	56	07·5	07	04	56·4	22	26·6		11	53	51·2
06	06	45	33·3	22	57·7		11	56	05·2	07	05	16·1	22	26·0		11	53	49·0
08	06	45	53·1	22	57·3		11	56	02·8	07	05	35·8	22	25·4		11	53	46·9
10	06	46	12·8	22	56·9		11	56	00·5	07	05	55·6	22	24·8		11	53	44·7
12	06	46	32·5	22	56·4		11	55	58·1	07	06	15·3	22	24·1		11	53	42·5
14	06	46	52·2	22	56·0		11	55	55·8	07	06	35·0	22	23·5		11	53	40·3
16	06	47	11·9	22	55·5		11	55	53·5	07	06	54·7	22	22·9		11	53	38·2
18	06	47	31·6	22	55·1		11	55	51·1	07	07	14·4	22	22·2		11	53	36·0
20	06	47	51·3	22	54·6		11	55	48·8	07	07	34·1	22	21·6		11	53	33·8
22	06	48	11·0	22	54·2		11	55	46·5	07	07	53·8	22	20·9		11	53	31·7
	Thursday 3									**Wednesday 9**								
00	06	48	30·8	S. 22	53·7		11	55	44·1	07	12	10·1	S. 22	12·3		11	53	04·0
02	06	48	50·5	22	53·2		11	55	41·8	07	12	29·8	22	11·6		11	53	01·9
04	06	49	10·2	22	52·8		11	55	39·5	07	12	49·5	22	10·9		11	52	59·8
06	06	49	29·9	22	52·3		11	55	37·2	07	13	09·3	22	10·2		11	52	57·7
08	06	49	49·6	22	51·8		11	55	34·9	07	13	29·0	22	09·5		11	52	55·6
10	06	50	09·3	22	51·3		11	55	32·5	07	13	48·7	22	08·8		11	52	53·5
12	06	50	29·0	22	50·9		11	55	30·2	07	14	08·4	22	08·1		11	52	51·4
14	06	50	48·8	22	50·4		11	55	27·9	07	14	28·1	22	07·4		11	52	49·3
16	06	51	08·5	22	49·9		11	55	25·6	07	14	47·8	22	06·7		11	52	47·2
18	06	51	28·2	22	49·4		11	55	23·3	07	15	07·5	22	06·0		11	52	45·1
20	06	51	47·9	22	48·9		11	55	21·0	07	15	27·2	22	05·3		11	52	43·1
22	06	52	07·6	22	48·4		11	55	18·7	07	15	47·0	22	04·5		11	52	41·0
	Friday 4									**Thursday 10**								
00	06	52	27·3	S. 22	47·9		11	55	16·4	07	16	06·7	S. 22	03·8		11	52	38·9
02	06	52	47·0	22	47·4		11	55	14·1	07	16	26·4	22	03·1		11	52	36·9
04	06	53	06·7	22	46·9		11	55	11·8	07	16	46·1	22	02·4		11	52	34·8
06	06	53	26·5	22	46·4		11	55	09·5	07	17	05·8	22	01·6		11	52	32·8
08	06	53	46·2	22	45·9		11	55	07·3	07	17	25·5	22	00·9		11	52	30·7
10	06	54	05·9	22	45·4		11	55	05·0	07	17	45·2	22	00·2		11	52	28·7
12	06	54	25·6	22	44·9		11	55	02·7	07	18	05·0	21	59·4		11	52	26·6
14	06	54	45·3	22	44·3		11	55	00·4	07	18	24·7	21	58·7		11	52	24·6
16	06	55	05·0	22	43·8		11	54	58·1	07	18	44·4	21	58·0		11	52	22·5
18	06	55	24·7	22	43·3		11	54	55·9	07	19	04·1	21	57·2		11	52	20·5
20	06	55	44·5	22	42·8		11	54	53·6	07	19	23·8	21	56·5		11	52	18·5
22	06	56	04·2	22	42·2		11	54	51·3	07	19	43·5	21	55·7		11	52	16·5
	Saturday 5									**Friday 11**								
00	06	56	23·9	S. 22	41·7		11	54	49·1	07	20	03·2	S. 21	55·0		11	52	14·5
02	06	56	43·6	22	41·1		11	54	46·8	07	20	22·9	21	54·2		11	52	12·4
04	06	57	03·3	22	40·6		11	54	44·5	07	20	42·7	21	53·4		11	52	10·4
06	06	57	23·0	22	40·0		11	54	42·3	07	21	02·4	21	52·7		11	52	08·4
08	06	57	42·7	22	39·5		11	54	40·0	07	21	22·1	21	51·9		11	52	06·4
10	06	58	02·4	22	39·0		11	54	37·8	07	21	41·8	21	51·1		11	52	04·4
12	06	58	22·2	22	38·4		11	54	35·5	07	22	01·5	21	50·4		11	52	02·4
14	06	58	41·9	22	37·8		11	54	33·3	07	22	21·2	21	49·6		11	52	00·4
16	06	59	01·6	22	37·3		11	54	31·0	07	22	40·9	21	48·8		11	51	58·4
18	06	59	21·3	22	36·7		11	54	28·8	07	23	00·6	21	48·0		11	51	56·5
20	06	59	41·0	22	36·2		11	54	26·6	07	23	20·4	21	47·2		11	51	54·5
22	07	00	00·7	S. 22	35·6		11	54	24·3	07	23	40·1	S. 21	46·4		11	51	52·5

R. is the Right Ascension of the Mean Sun $\pm$ 12 hours. *E.* is 12 hours minus the Equation of Time.

JANUARY, 1929.

MOON'S RIGHT ASCENSION AND DECLINATION.

G.M.T.	R.A.				Thursday 17				Dec.		G.M.T.	R.A.				Monday 21				Dec.	
h.	h.	m.	s.	s.		°	′		′		h.	h.	m.	s.	s.		°	′		′
00	00	28	26	238	S.	1	20·2		29·6		00	03	56	44	298	N.	20	41·5		20·7
02	00	32	24	238		0	50·6		29·6		02	04	01	42	299		21	02·2		20·2
04	00	36	22	239	S.	0	21·0		29·7		04	04	06	41	301		21	22·4		19·7
06	00	40	21	239	N.	0	08·7		29·7		06	04	11	42	303		21	42·1		19·2
08	00	44	20	239		0	38·4		29·7		08	04	16	45	304		22	01·3		18·6
10	00	48	19	240		1	08·1		29·8		10	04	21	49	307		22	19·9		18·0
12	00	52	19	241		1	37·9		29·9		12	04	26	56	308		22	37·9		17·5
14	00	56	20	241		2	07·8		29·8		14	04	32	04	310		22	55·4		16·8
16	01	00	21	242		2	37·6		29·8		16	04	37	14	311		23	12·2		16·3
18	01	04	23	242		3	07·4		29·9		18	04	42	25	313		23	28·5		15·6
20	01	08	25	244		3	37·3		29·8		20	04	47	38	315		23	44·1		15·0
22	01	12	29	243	N.	4	07·1		29·8		22	04	52	53	317	N.	23	59·1		14·3
					Friday 18											**Tuesday 22**				
00	01	16	32	245	N.	4	36·9		29·8		00	04	58	10	317	N.	24	13·4		13·6
02	01	20	37	246		5	06·7		29·7		02	05	03	27	320		24	27·0		12·9
04	01	24	43	246		5	36·4		29·7		04	05	08	47	321		24	39·9		12·3
06	01	28	49	247		6	06·1		29·6		06	05	14	08	322		24	52·2		11·6
08	01	32	56	249		6	35·7		29·6		08	05	19	30	323		25	03·8		10·8
10	01	37	05	249		7	05·3		29·5		10	05	24	53	325		25	14·6		10·1
12	01	41	14	250		7	34·8		29·3		12	05	30	18	325		25	24·7		9·4
14	01	45	24	252		8	04·1		29·3		14	05	35	43	327		25	34·1		8·6
16	01	49	36	252		8	33·4		29·2		16	05	41	10	328		25	42·7		7·9
18	01	53	48	254		9	02·6		29·0		18	05	46	38	329		25	50·6		7·1
20	01	58	02	255		9	31·6		28·9		20	05	52	07	329		25	57·7		6·3
22	02	02	17	256	N.	10	00·5		28·8		22	05	57	36	331	N.	26	04·0		5·5
					Saturday 19											**Wednesday 23**				
00	02	06	33	258	N.	10	29·3		28·5		00	06	03	07	331	N.	26	09·5		4·8
02	02	10	51	259		10	57·8		28·5		02	06	08	38	331		26	14·3		4·0
04	02	15	10	260		11	26·3		28·2		04	06	14	09	332		26	18·3		3·2
06	02	19	30	261		11	54·5		28·0		06	06	19	41	332		26	21·5		2·3
08	02	23	51	263		12	22·5		27·9		08	06	25	13	333		26	23·8		1·6
10	02	28	14	265		12	50·4		27·6		10	06	30	46	333		26	25·4		0·8
12	02	32	39	266		13	18·0		27·4		12	06	36	19	333		26	26·2		0·0
14	02	37	05	267		13	45·4		27·1		14	06	41	52	332		26	26·2		0·9
16	02	41	32	270		14	12·5		26·9		16	06	47	24	333		26	25·3		1·6
18	02	46	02	270		14	39·4		26·5		18	06	52	57	333		26	23·7		2·5
20	02	50	32	273		15	05·9		26·4		20	06	58	30	332		26	21·2		3·2
22	02	55	05	274	N.	15	32·3		26·0		22	07	04	02	331	N.	26	18·0		4·0
					Sunday 20											**Thursday 24**				
00	02	59	39	275	N.	15	58·3		25·6		00	07	09	33	332	N.	26	14·0		4·9
02	03	04	14	278		16	23·9		25·4		02	07	15	05	330		26	09·1		5·6
04	03	08	52	279		16	49·3		25·0		04	07	20	35	330		26	03·5		6·4
06	03	13	31	281		17	14·3		24·7		06	07	26	05	329		25	57·1		7·2
08	03	18	12	283		17	39·0		24·2		08	07	31	34	328		25	49·9		7·9
10	03	22	55	284		18	03·2		23·9		10	07	37	02	328		25	42·0		8·7
12	03	27	39	286		18	27·1		23·5		12	07	42	30	326		25	33·3		9·4
14	03	32	25	289		18	50·6		23·1		14	07	47	56	325		25	23·9		10·2
16	03	37	14	290		19	13·7		22·6		16	07	53	21	324		25	13·7		11·0
18	03	42	04	291		19	36·3		22·2		18	07	58	45	322		25	02·7		11·6
20	03	46	55	294		19	58·5		21·7		20	08	04	07	321		24	51·1		12·4
22	03	51	49	295		20	20·2		21·3		22	08	09	28	320		24	38·7		13·0
24	03	56	44		N.	20	41·5				24	08	14	48		N.	24	25·7		

JANUARY, 1929.

0h	VENUS.							MARS.						
	R.A.			Dec.			Meridian Passage.	R.A.			Dec.			Meridian Passage.
	h. m. s.	s.		° ′	′		h. m.	h. m. s.	s.		° ′	′		h. m.
Tues. 1	21 46 09	269		S 15 17·3	25·7		15 06	05 40 21	89		N. 26 47·3	0·1		22 55
Wed. 2	21 50 38	268		14 51·6	26·0		15 06	05 38 52	86		26 47·2	0·2		22 49
Thur. 3	21 55 06	266		14 25·6	26·3		15 07	05 37 26	83		26 47·0	0·2		22 44
Fri. 4	21 59 32	265		13 59·3	26·7		15 07	05 36 03	80		26 46·8	0·4		22 39
Sat. 5	22 03 57	262		13 32·6	26·9		15 08	05 34 43	78		26 46·4	0·5		22 33
Sun. 6	22 08 19	262		13 05·7	27·3		15 08	05 33 25	74		26 45·9	0·6		22 28
Mon. 7	22 12 41	259		12 38·4	27·6		15 09	05 32 11	71		26 45·3	0·6		22 23
Tues. 8	22 17 00	258		12 10·8	27·8		15 09	05 31 00	68		26 44·7	0·7		22 18
Wed. 9	22 21 18	257		11 43·0	28·1		15 09	05 29 52	64		26 44·0	0·8		22 13
Thur. 10	22 25 35	255		11 14·9	28·3		15 10	05 28 48	61		26 43·2	0·8		22 08
Fri. 11	22 29 50	253		10 46·6	28·5		15 10	05 27 47	57		26 42·4	0·9		22 03
Sat. 12	22 34 03	252		10 18·1	28·8		15 10	05 26 50	54		26 41·5	0·9		21 58
Sun. 13	22 38 15	250		9 49·3	29·0		15 10	05 25 56	50		26 40·6	0·9		21 54
Mon. 14	22 42 25	248		9 20·3	29·1		15 11	05 25 06	47		26 39·7	1·0		21 49
Tues. 15	22 46 33	247		8 51·2	29·4		15 11	05 24 19	43		26 38·7	0·9		21 44
Wed. 16	22 50 40	246		8 21·8	29·5		15 11	05 23 36	39		26 37·8	1·0		21 40
Thur. 17	22 54 46	244		7 52·3	29·6		15 11	05 22 57	35		26 36·8	1·0		21 35
Fri. 18	22 58 50	243		7 22·7	29·8		15 11	05 22 22	32		26 35·8	1·0		21 31
Sat. 19	23 02 53	241		6 52·9	30·0		15 11	05 21 50	28		26 34·8	1·0		21 26
Sun. 20	23 06 54	239		6 22·9	30·0		15 11	05 21 22	24		26 33·8	1·0		21 22
Mon. 21	23 10 53	238		5 52·9	30·1		15 11	05 20 58	21		26 32·8	0·9		21 18
Tues. 22	23 14 51	237		5 22·8	30·2		15 11	05 20 37	17		26 31·9	1·0		21 14
Wed. 23	23 18 48	235		4 52·6	30·3		15 11	05 20 20	14		26 30.9	0·9		21 09
Thur. 24	23 22 43	234		4 22·3	30·3		15 11	05 20 06	10		26 30·0	0·9		21 05
Fri. 25	23 26 37	232		3 52·0	30·4		15 11	05 19 56	7		26 29·1	0·9		21 01
Sat. 26	23 30 29	231		3 21·6	30·4		15 11	05 19 49	3		26 28·2	0·9		20 57
Sun. 27	23 34 20	229		2 51·2	30·5		15 11	05 19 46	1		26 27·3	0·9		20 53
Mon. 28	23 38 09	228		2 20·7	30·4		15 11	05 19 47	3		26 26·4	0·8		20 49
Tues. 29	23 41 57	226		1 50·3	30·5		15 11	05 19 50	7		26 25·6	0·8		20 46
Wed. 30	23 45 43	225		1 19·8	30·4		15 11	05 19 57	10		26 24·8	0·7		20 42
Thur. 31	23 49 28	224		0 49·4	30·5		15 10	05 20 07	14		26 24·1	0·7		20 38
Fri. 32	23 53 12			S 0 18·9			15 10	05 20 21			N. 26 23·4			20 34

MARCH, 1929.

Star's Name.	Mag.	Right Ascension.	Declination.
		h. m. s.	° ′
α Phœnicis,	2·4	00 22 45	S. 42 41·6
β Andromedæ,	2·4	01 05 43	N. 35 14·6
α Ursæ Minoris, *Polaris*	2·1	01 35 02	N. 88 55·6
α Eridani, *Achernar*	0·6	01 35 03	S. 57 36·0
γ Andromedæ,	2·2	01 59 30	N. 41 59·4
α Arietis, *Hamal*	2·2	02 03 08	N. 23 07·6
α Persei, *Mirfak*	1·9	03 19 13	N. 49 36·8
α Tauri, *Aldebaran*	1·1	04 31 50	N. 16 22·1
β Orionis, *Rigel*	0·3	05 11 07	S. 8 17·0
α Aurigæ, *Capella*	0·2	05 11 26	N. 45 55·9
γ Orionis, *Bellatrix*	1·7	05 21 19	N. 6 17·2
β Tauri, *Nath*	1·8	05 21 48	N. 28 33·1
ε Orionis,	1·8	05 32 36	S. 1 14·8
ζ Orionis,	1·9	05 37 10	S. 1 58·8
α Orionis, *Betelguese*	0·5-1·1	05 51 19	N. 7 23·7
β Aurigæ,	2·1	05 54 19	N. 44 56·7
β Canis Majoris, *Mirzam*	2·0	06 19 34	S. 17 55·3
α Argus, *Canopus*	−0·9	06 22 23	S. 52 39·6
γ Geminorum. *Alhena*	1·9	06 33 37	N. 16 27·7
α Canis Majoris, *Sirius*	−1·6	06 42 01	S. 16 37·2
ε Canis Majoris,	1·6	06 55 50	S. 28 52·6
δ Canis Majoris,	2·0	07 05 30	S. 26 16·9
α Geminorum, *Castor*	1·6	07 30 05	N. 32 02·9
α Canis Minoris, *Procyon*	0·5	07 35 36	N. 5 24·5
β Geminorum, *Pollux*	1·2	07 40 59	N. 28 12·1
γ Argus,	1·9	08 07 21	S. 47 07·8
ε Argus,	1·7	08 21 05	S. 59 17·0
δ Argus,	2·0	08 42 46	S. 54 27·0
β Argus,	1·8	09 12 28	S. 69 25·6
α Hydræ, *Alphard*	2·2	09 24 07	S. 8 21·1
α Leonis, *Regulus*	1·3	10 04 37	N. 12 18·9
γ Leonis,	2·3	10 16 05	N. 20 12·1
β Ursæ Majoris,	2·4	10 57 37	N. 56 45·8
α Ursæ Majoris, *Dubhe*	2·0	10 59 25	N. 62 08·1
β Leonis, *Denebola*	2·2	11 45 27	N. 14 58·0
α Crucis,	1·1	12 22 40	S. 62 42·3
γ Crucis,	1·6	12 27 14	S. 56 42·9
β Crucis,	1·5	12 43 35	S. 59 18·0
ε Ursæ Majoris, *Alioth*	1·7	12 50 57	N. 56 20·5
ζ Ursæ Majoris, *Mizar*	2·2	13 21 06	N. 55 17·5
α Virginis, *Spica*	1·2	13 21 28	S. 10 47·6
η Ursæ Majoris, *Benetnasch*	1·9	13 44 46	N. 49 39·8
β Centauri,	0·9	13 58 49	S. 60 01·8
α Bootis, *Arcturus*	0·2	14 12 26	N. 19 32·8
α Centauri,	0·1	14 34 47	S. 60 32·5
β Ursæ Minoris, *Kochab*	2·2	14 50 57	N. 74 26·4
α Coronæ Borealis, *Alphacca*	2·3	15 31 41	N. 26 56·9
α Scorpii, *Antares*	1·2	16 25 03	S. 26 16·6
α Trianguli Australis,	1·9	16 41 08	S. 68 53·8
λ Scorpii,	1·7	17 28 47	S. 37 03·2
α Ophiuchi,	2·1	17 31 38	N. 12 36·3
θ Scorpii,	2·0	17 32 12	S. 42 57·2
ε Sagittarii,	2·0	18 19 27	S. 34 25·2
α Lyræ, *Vega*	0·1	18 34 31	N. 38 42·6
σ Sagittarii,	2·1	18 50 51	S. 26 23·3
α Aquilæ, *Altair*	0·9	19 47 18	N. 8 40·5
α Pavonis,	2·1	20 20 01	S. 56 57·8
α Cygni, *Deneb*	1·3	20 38 59	N. 45 01·2
α Piscis Australis, *Fomalhaut*	1·3	22 53 42	S. 30 00·1

MARCH, 1929.

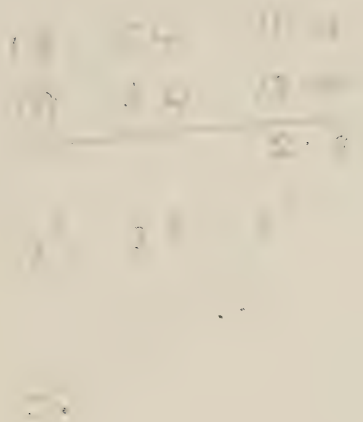
Date.		Day of Year.	Sun's Semi-diameter.	THE MOON'S								
				Semi-diameter.	Horizontal Parallax.	Meridian Passage.						Age at 0h.
						Upper.		Diff.	Lower.		Diff.	
			′	′	′	h.	m.	m.	h.	m.	m.	d.
Fri.	1	60	16·2	15·0	55·1	04	18	45	16	40	46	19·3
Sat.	2	61	16·2	14·9	54·7	05	03	47	17	26	48	20·3
Sun.	**3**	62	16·2	14·8	54·4	05	50	48	18	14	49	21·3
Mon.	4	63	16·2	14·8	54·2	06	38	51	19	03	51	22·3
Tues.	5	64	16·1	14·8	54·3	07	29	51	19	54	52	23·3
Wed.	6	65	16·1	14·9	54·5	08	20	51	20	46	50	24·3
Thur.	7	66	16·1	15·0	54·9	09	11	51	21	36	50	25·3
Fri.	8	67	16·1	15·1	55·4	10	02	49	22	26	48	26·3
Sat.	9	68	16·1	15·2	55·9	10	51	47	23	14	47	27·3
Sun.	**10**	69	16·1	15·4	56·6	11	38	46	*	*		28·3
Mon.	11	70	16·1	15·6	57·2	12	24	47	00	01	47	29·3
Tues.	12	71	16·1	15·7	57·8	13	11	47	00	48	46	0·6
Wed.	13	72	16·1	15·9	58·3	13	58	48	01	34	48	1·6
Thur.	14	73	16·1	16·0	58·7	14	46	52	02	22	50	2·6
Fri.	15	74	16·1	16·1	59·0	15	38	55	03	12	53	3·6
Sat.	16	75	16·1	16·1	59·2	16	33	59	04	05	57	4·6
Sun.	**17**	76	16·1	16·1	59·2	17	32	61	05	02	60	5·6
Mon.	18	77	16·1	16·1	59·3	18	33	62	06	02	62	6·6
Tues.	19	78	16·1	16·1	59·2	19	35	59	07	04	61	7·6
Wed.	20	79	16·1	16·1	59·0	20	34	57	08	05	58	8·6
Thur.	21	80	16·1	16·0	58·8	21	31	52	09	03	55	9·6
Fri.	22	81	16·1	15·9	58·5	22	23	49	09	58	50	10·6
Sat.	23	82	16·1	15·8	58·1	23	12	46	10	48	47	11·6
Sun.	**24**	83	16·1	15·7	57·7	23	58	44	11	35	45	12·6
Mon.	25	84	16·1	15·6	57·1	*	*		12	20	44	13·6
Tues.	26	85	16·1	15·4	56·6	00	42	44	13	04	44	14·6
Wed.	27	86	16·0	15·3	56·0	01	26	44	13	48	44	15·6
Thur.	28	87	16·0	15·1	55·4	02	10	45	14	32	46	16·6
Fri.	29	88	16·0	15·0	55·0	02	55	47	15	18	48	17·6
Sat.	30	89	16·0	14·9	54·6	03	42	48	16	06	49	18·6
Sun.	**31**	90	16·0	14·8	54·3	04	30	50	16	55	50	19·6
Mon.	32	91	16·0	14·8	54·2	05	20		17	45		20·6

MARCH, 1929.

THE SUN.

G.M.T.	Saturday 16							Thursday 21						
	R.			Dec.		*E.*		*R.*			Dec.		*E.*	
h.	h.	m.	s.	°	′	h.	m.	s.	h.	m.	s.	°	′	h.	m.	s.
00	11	32	22·8	S. 2	01·1	11	51	01·3	11	52	05·5	S. 0	02·5	11	52	29·1
02	11	32	42·5	1	59·1	11	51	02·7	11	52	25·3	S. 0	00·6	11	52	30·6
04	11	33	02·2	1	57·2	11	51	04·1	11	52	45·0	N. 0	01·4	11	52	32·1
06	11	33	21·9	1	55·2	11	51	05·6	11	53	04·7	0	03·4	11	52	33·6
08	11	33	41·6	1	53·2	11	51	07·0	11	53	24·4	0	05·4	11	52	35·1
10	11	34	01·3	1	51·2	11	51	08·4	11	53	44·1	0	07·3	11	52	36·6
12	11	34	21·1	1	49·3	11	51	09·8	11	54	03·8	0	09·3	11	52	38·1
14	11	34	40·8	1	47·3	11	51	11·3	11	54	23·5	0	11·3	11	52	39·6
16	11	35	00·5	1	45·3	11	51	12·7	11	54	43·2	0	13·2	11	52	41·2
18	11	35	20·2	1	43·3	11	51	14·2	11	55	03·0	0	15·2	11	52	42·7
20	11	35	39·9	1	41·4	11	51	15·6	11	55	22·7	0	17·2	11	52	44·2
22	11	35	59·6	1	39·4	11	51	17·0	11	55	42·4	0	19·2	11	52	45·7
	Monday 18							Friday 22						
00	11	40	15·9	S. 1	13·7	11	51	35·8	11	56	02·1	N. 0	21·1	11	52	47·2
02	11	40	35·6	1	11·7	11	51	37·3	11	56	21·8	0	23·1	11	52	48·7
04	11	40	55·3	1	09·7	11	51	38·8	11	56	41·5	0	25·1	11	52	50·2
06	11	41	15·0	1	07·8	11	51	40·2	11	57	01·2	0	27·1	11	52	51·7
08	11	41	34·7	1	05·8	11	51	41·7	11	57	20·9	0	29·0	11	52	53·2
10	11	41	54·4	1	03·8	11	51	43·1	11	57	40·7	0	31·0	11	52	54·8
12	11	42	14·2	1	01·8	11	51	44·6	11	58	00·4	0	33·0	11	52	56·3
14	11	42	33·9	0	59·9	11	51	46·1	11	58	20·1	0	35·0	11	52	57·8
16	11	42	53·6	0	57·9	11	51	47·5	11	58	39·8	0	36·9	11	52	59·3
18	11	43	13·3	0	55·9	11	51	49·0	11	58	59·5	0	38·9	11	53	00·8
20	11	43	33·0	0	53·9	11	51	50·5	11	59	19·2	0	40·9	11	53	02·3
22	11	43	52·7	0	52·0	11	51	51·9	11	59	38·9	0	42·8	11	53	03·9
	Tuesday 19							Saturday 23						
00	11	44	12·4	S. 0	50·0	11	51	53·4	11	59	58·6	N. 0	44·8	11	53	05·4
02	11	44	32·1	0	48·0	11	51	54·9	12	00	18·4	0	46·8	11	53	06·9
04	11	44	51·9	0	46·0	11	51	56·4	12	00	38·1	0	48·8	11	53	08·4
06	11	45	11·6	0	44·0	11	51	57·8	12	00	57·8	0	50·7	11	53	09·9
08	11	45	31·3	0	42·1	11	51	59·3	12	01	17·5	0	52·7	11	53	11·5
10	11	45	51·0	0	40·1	11	52	00·8	12	01	37·2	0	54·7	11	53	13·0
12	11	46	10·7	0	38·1	11	52	02·3	12	01	56·9	0	56·6	11	53	14·5
14	11	46	30·4	0	36·1	11	52	03·8	12	02	16·6	0	58·6	11	53	16·0
16	11	46	50·1	0	34·2	11	52	05·2	12	02	36·3	1	00·6	11	53	17·6
18	11	47	09·8	0	32·2	11	52	06·7	12	02	56·1	1	02·6	11	53	19·1
20	11	47	29·6	0	30·2	11	52	08·2	12	03	15·8	1	04·5	11	53	20·6
22	11	47	49·3	0	28·2	11	52	09·7	12	03	35·5	1	06·5	11	53	22·1
	Wednesday 20							Sunday 24						
00	11	48	09·0	S. 0	26·3	11	52	11·2	12	03	55·2	N. 1	08·5	11	53	23·7
02	11	48	28·7	0	24·3	11	52	12·7	12	04	14·9	1	10·4	11	53	25·2
04	11	48	48·4	0	22·3	11	52	14·2	12	04	34·6	1	12·4	11	53	26·7
06	11	49	08·1	0	20·3	11	52	15·7	12	04	54·3	1	14·4	11	53	28·3
08	11	49	27·8	0	18·4	11	52	17·2	12	05	14·1	1	16·3	11	53	29·8
10	11	49	47·5	0	16·4	11	52	18·6	12	05	33·8	1	18·3	11	53	31·3
12	11	50	07·3	0	14·4	11	52	20·1	12	05	53·5	1	20·3	11	53	32·8
14	11	50	27·0	0	12·4	11	52	21·6	12	06	13·2	1	22·2	11	53	34·4
16	41	50	46.7	0	10·5	11	52	23·1	12	06	32·9	1	24·2	11	53	35·9
18	11	51	06·4	0	08·5	11	52	24·6	12	06	52·6	1	26·2	11	53	37·4
20	11	51	26·1	0	06·5	11	52	26·1	12	07	12·3	1	28·1	11	53	39·0
22	11	51	45·8	S. 0	04·5	11	52	27·6	12	07	32·0	N. 1	30·1	11	53	40·5

R. is the Right Ascension of the Mean Sun ± 12 hours. *E.* is 12 hours minus the Equation of Time.



APRIL, 1929.

Star's Name.	Mag.	Right Ascension.	Declination.
		h. m. s.	° ′
α Phœnicis,	2·4	00 22 46	S. 42 41·5
α Ursæ Minoris, *Polaris*	2·1	01 34 55	N. 88 55·4
α Eridani, *Achernar*	0·6	01 35 03	S. 57 35·8
γ Andromedæ,	2·2	01 59 30	N. 41 59·4
α Persei, *Mirfak*	1·9	03 19 12	N. 49 36·7
α Tauri, *Aldebaran*	1·1	04 31 50	N. 16 22·1
β Orionis, *Rigel*	0·3	05 11 07	S. 8 17·0
α Aurigæ, *Capella*	0·2	05 11 25	N. 45 55·8
γ Orionis, *Bellatrix*	1·7	05 21 18	N. 6 17·2
β Tauri, *Nath*	1·8	05 21 47	N. 28 33·1
ε Orionis,	1·8	05 32 36	S. 1 14·8
ζ Orionis,	1·9	05 37 10	S. 1 58·7
α Orionis, *Betelguese*	0·5-1·1	05 51 19	N. 7 23·7
β Aurigæ,	2·1	05 54 18	N. 44 56·7
β Canis Majoris, *Mirzam*	?·0	06 19 34	S. 17 55·3
α Argus, *Canopus*	−0·9	06 22 22	S. 52 39·6
γ Geminorum, *Alhena*	1·9	06 33 36	N. 16 27·7
α Canis Majoris, *Sirius*	−1·6	06 42 01	S. 16 37·2
ε Canis Majoris,	1·6	06 55 50	S. 28 52·6
δ Canis Majoris,	2·0	07 05 30	S. 26 16·9
α Geminorum, *Castor*	1·6	07 30 04	N. 32 02·9
α Canis Minoris, *Procyon*	0·5	07 35 35	N. 5 24·5
β Geminorum, *Pollux*	1·2	07 40 58	N. 28 12·1
ν Argus,	1·9	08 07 20	S. 47 07·8
ε Argus,	1·7	08 21 03	S. 59 17·1
δ Argus,	2·0	08 42 45	S. 54 27·1
β Argus,	1·8	09 12 26	S. 69 25·7
α Hydræ, *Alphard*	2·2	09 24 06	S. 8 21·1
α Leonis, *Regulus*	1·3	10 04 36	N. 12 18·9
γ Leonis,	2·3	10 16 05	N. 20 12·1
β Ursæ Majoris,	2·4	10 57 36	N. 56 46·0
α Ursæ Majoris, *Dubhe*	2·0	10 59 24	N. 62 08·3
β Leonis, *Denebola*	2·2	11 45 28	N. 14 58·1
α Crucis,	1·1	12 22 40	S. 62 42·5
γ Crucis,	1·6	12 27 14	S. 56 43·1
β Crucis,	1·5	12 43 35	S. 59 18·2
ε Ursæ Majoris, *Alioth*	1·7	12 50 57	N. 56 20·7
ζ Ursæ Majoris, *Mizar*	2·2	13 21 07	N. 55 17·6
α Virginis, *Spica*	1·2	13 21 28	S. 10 47·6
η Ursæ Majoris, *Benetnasch*	1·9	13 44 47	N. 49 39·9
β Centauri,	0·9	13 58 50	S. 60 02·0
α Bootis, *Arcturus*	0·2	14 12 27	N. 19 32·9
α Centauri,	0·1	14 34 48	S. 60 32·6
β Ursæ Minoris, *Kochab*	2·2	14 50 59	N. 74 26·5
α Coronæ Borealis, *Alphacca*	2·3	15 31 42	N. 26 56·9
α Scorpii, *Antares*	1·2	16 25 04	S. 26 16·7
α Trianguli Australis,	1·9	16 41 10	S. 68 53·9
λ Scorpii,	1·7	17 28 48	S. 37 03·3
α Ophiuchi,	2·1	17 31 39	N. 12 36·3
θ Scorpii,	2·0	17 32 14	S. 42 57·3
ε Sagittarii,	2·0	18 19 28	S. 34 25·2
α Lyræ, *Vega*	0·1	18 34 32	N. 38 42·6
σ Sagittarii,	2·1	18 50 52	S. 26 23·3
α Aquilæ, *Altair*	0·9	19 47 19	N. 8 40·5
α Pavonis,	2·1	20 20 02	S. 56 57·7
α Cygni, *Deneb*	1·3	20 39 00	N. 45 01·2
α Gruis,	2·2	22 03 45	S. 47 18·3
β Gruis,	2·2	22 38 25	S. 47 15·3
α Piscis Australis, *Fomalhaut*	1·3	22 53 43	S. 30 00·0

APRIL, 1929.

Date.		Day of Year.	Sun's Semi-diameter.	THE MOON'S								
				Semi-diameter.	Horizontal Parallax.	Meridian Passage.						Age at 0h.
						Upper.		Diff.	Lower.		Diff.	
			′	′	′	h.	m.	m.	h.	m.	m.	d.
Mon.	1	91	16·0	14·8	54·2	05	20	51	17	45	51	20·6
Tues.	2	92	16·0	14·8	54·3	06	11	51	18	36	51	21·6
Wed.	3	93	16·0	14·9	54·6	07	02	50	19	27	50	22·6
Thur.	4	94	16·0	15·0	55·0	07	52	49	20	17	48	23·6
Fri.	5	95	16·0	15·1	55·5	08	41	48	21	05	47	24·6
Sat.	6	96	16·0	15·3	56·2	09	29	46	21	52	47	25·6
Sun.	7	97	16·0	15·5	57·0	10	15	47	22	39	46	26·6
Mon.	8	98	16·0	15·7	57·8	11	02	47	23	25	48	27·6
Tues.	9	99	16·0	15·9	58·5	11	49	49	*	*		28·6
Wed.	10	100	16·0	16·1	59·1	12	38	52	00	13	50	0·1
Thur.	11	101	16·0	16·2	59·6	13	30	55	01	03	54	1·1
Fri.	12	102	16·0	16·3	59·9	14	25	59	01	57	57	2·1
Sat.	13	103	16·0	16·3	59·9	15	24	62	02	54	61	3·1
Sun.	14	104	16·0	16·3	59·8	16	26	63	03	55	63	4·1
Mon.	15	105	16·0	16·2	59·6	17	29	61	04	58	62	5·1
Tues.	16	106	16·0	16·1	59·2	18	30	57	06	00	59	6·1
Wed.	17	107	16·0	16·0	58·8	19	27	53	06	59	55	7·1
Thur.	18	108	15·9	15·9	58·3	20	20	49	07	54	51	8·1
Fri.	19	109	15·9	15·8	57·8	21	09	45	08	45	47	9·1
Sat.	20	110	15·9	15·6	57·3	21	54	44	09	32	44	10·1
Sun.	21	111	15·9	15·5	56·8	22	38	43	10	16	44	11·1
Mon.	22	112	15·9	15·4	56·3	23	21	44	11	00	43	12·1
Tues.	23	113	15·9	15·2	55·9	*	*		11	43	44	13·1
Wed.	24	114	15·9	15·1	55·4	00	05	44	12	27	45	14·1
Thur.	25	115	15·9	15·0	55·0	00	49	46	13	12	47	15·1
Fri.	26	116	15·9	14·9	54·6	01	35	48	13	59	48	16·1
Sat.	27	117	15·9	14·8	54·4	02	23	49	14	47	50	17·1
Sun.	28	118	15·9	14·8	54·2	03	12	51	15	37	51	18·1
Mon.	29	119	15·9	14·8	54·1	04	03	51	16	28	51	19·1
Tues.	30	120	15·9	14·8	54·2	04	54	50	17	19	49	20·1
Wed.	31	121	15·9	14·9	54·5	05	44		18	08		21·1

APRIL, 1929.

THE SUN.

G.M.T.	Saturday 13									Wednesday 17								
	R.			Dec.			*E.*			*R.*			Dec.			*E.*		
h.	h.	m.	s.	°	′		h.	m.	s.	h.	m.	s.	°	′		h.	m.	s.
00	13	22	46·3	N. 8	47·3		11	59	15·1	13	38	32·5	N. 10	13·5		12	00	14·9
02	13	23	06·0	8	49·1		11	59	16·4	13	38	52·2	10	15·3		12	00	16·1
04	13	23	25·7	8	51·0		11	59	17·6	13	39	11·9	10	17·1		12	00	17·3
06	13	23	45·4	8	52·8		11	59	18·9	13	39	31·6	10	18·8		12	00	18·5
08	13	24	05·1	8	54·6		11	59	20·2	13	39	51·3	10	20·6		12	00	19·7
10	13	24	24·8	8	56·4		11	59	21·5	13	40	11·1	10	22·4		12	00	20·8
12	13	24	44·6	8	58·2		11	59	22·8	13	40	30·8	10	24·1		12	00	22·0
14	13	25	04·3	9	00·0		11	59	24·1	13	40	50·5	10	25·9		12	00	23·2
16	13	25	24·0	9	01·9		11	59	25·4	13	41	10·2	10	27·7		12	00	24·4
18	13	25	43·7	9	03·7		11	59	26·7	13	41	29·9	10	29·4		12	00	25·5
20	13	26	03·4	9	05·5		11	59	27·9	13	41	49·6	10	31·2		12	00	26·7
22	13	26	23·1	9	07·3		11	59	29·2	13	42	09·3	10	32·9		12	00	27·9
	Sunday 14									Thursday 18								
00	13	26	42·8	N. 9	09·1		11	59	30·5	13	42	29·0	N. 10	34·7		12	00	29·0
02	13	27	02·5	9	10·9		11	59	31·8	13	42	48·8	10	36·4		12	00	30·2
04	13	27	22·3	9	12·7		11	59	33·0	13	43	08·5	10	38·2		12	00	31·3
06	13	27	42·0	9	14·5		11	59	34·3	13	43	28·2	10	39·9		12	00	32·5
08	13	28	01·7	9	16·3		11	59	35·6	13	43	47·9	10	41·7		12	00	33·7
10	13	28	21·4	9	18·1		11	59	36·8	13	44	07·6	10	43·4		12	00	34·8
12	13	28	41·1	9	19·9		11	59	38·1	13	44	27·3	10	45·2		12	00	35·9
14	13	29	00·8	9	21·7		11	59	39·4	13	44	47·0	10	46·9		12	00	37·1
16	13	29	20·5	9	23·5		11	59	40·6	13	45	06·7	10	48·7		12	00	38·2
18	13	29	40·2	9	25·3		11	59	41·9	13	45	26·5	10	50·4		12	00	39·4
20	13	30	00·0	9	27·1		11	59	43·1	13	45	46·2	10	52·2		12	00	40·5
22	13	30	19·7	9	28·9		11	59	44·4	13	46	05·9	10	53·9		12	00	41·7
	Monday 15									Friday 19								
00	13	30	39·4	N. 9	30·7		11	59	45·6	13	46	25·6	N. 10	55·7		12	00	42·8
02	13	30	59·1	9	32·5		11	59	46·9	13	46	45·3	10	57·4		12	00	43·9
04	13	31	18·8	9	34·3		11	59	48·1	13	47	05·0	10	59·1		12	00	45·0
06	13	31	38·5	9	36·1		11	59	49·4	13	47	24·7	11	00·9		12	00	46·2
08	13	31	58·2	9	37·9		11	59	50·6	13	47	44·4	11	02·6		12	00	47·3
10	13	32	17·9	9	39·7		11	59	51·8	13	48	04·2	11	04·3		12	00	48·4
12	13	32	37·7	9	41·5		11	59	53·1	13	48	23·9	11	06·1		12	00	49·5
14	13	32	57·4	9	43·3		11	59	54·3	13	48	43·6	11	07·8		12	00	50·6
16	13	33	17·1	9	45·1		11	59	55·5	13	49	03·3	11	09·5		12	00	51·7
18	13	33	36·8	9	46·9		11	59	56·8	13	49	23·0	11	11·3		12	00	52·8
20	13	33	56·5	9	48·7		11	59	58·0	13	49	42·7	11	13·0		12	00	53·9
22	13	34	16·2	9	50·4		11	59	59·2	13	50	02·4	11	14·7		12	00	55·0
	Tuesday 16									Saturday 20								
00	13	34	35·9	N. 9	52·2		12	00	00·4	13	50	22·1	N. 11	16·4		12	00	56·1
02	13	34	55·6	9	54·0		12	00	01·7	13	50	41·9	11	18·2		12	00	57·2
04	13	35	15·4	9	55·8		12	00	02·9	13	51	01·6	11	19·9		12	00	58·3
06	13	35	35·1	9	57·6		12	00	04·1	13	51	21·3	11	21·6		12	00	59·4
08	13	35	54·8	9	59·3		12	00	05·3	13	51	41·0	11	23·3		12	01	00·5
10	13	36	14·5	10	01·1		12	00	06·5	13	52	00·7	11	25·0		12	01	01·6
12	13	36	34·2	10	02·9		12	00	07·7	13	52	20·4	11	26·8		12	01	02·7
14	13	36	53·9	10	04·7		12	00	08·9	13	52	40·1	11	28·5		12	01	03·8
16	13	37	13·6	10	06·4		12	00	10·1	13	52	59·9	11	30·2		12	01	04·8
18	13	37	33·3	10	08·2		12	00	11·3	13	53	19·6	11	31·9		12	01	05·9
20	13	37	53·1	10	10·0		12	00	12·5	13	53	39·3	11	33·6		12	01	07·0
22	13	38	12·8	N. 10	11·8		12	00	13·7	13	53	59·0	N. 11	35·3		12	01	08·0

R. is the Right Ascension of the Mean Sun ± 12 hours. *E.* is 12 hours minus the Equation of Time.

APRIL, 1929.

MOON'S RIGHT ASCENSION AND DECLINATION.

G.M.T.	R.A.		Thursday 25	Dec.		G.M.T.	R.A.		Sunday 28	Dec.	
h.	h. m. s.	s.	° ′	′		h.	h. m. s.	s.	° ′	′	
00	14 57 29	238	S. 16 26·4	22·6		00	17 27 43	262	S. 26 00·4	7·8	
02	15 01 27	239	16 49·0	22·3		02	17 32 05	262	26 08·2	7·2	
04	15 05 26	240	17 11·3	22·0		04	17 36 27	263	26 15·4	6·7	
06	15 09 26	240	17 33·3	21·7		06	17 40 50	263	26 22·1	6·2	
08	15 13 26	241	17 55·0	21·3		08	17 45 13	264	26 28·3	5·7	
10	15 17 27	241	18 16·3	21·0		10	17 49 37	264	26 34·0	5·2	
12	15 21 28	243	18 37·3	20·7		12	17 54 01	264	26 39·2	4·7	
14	15 25 31	243	18 58·0	20·3		14	17 58 25	264	26 43·9	4·2	
16	15 29 34	243	19 18·3	19·9		16	18 02 49	265	26 48·1	3·6	
18	15 33 37	245	19 38·2	19·6		18	18 07 14	265	26 51·7	3·2	
20	15 37 42	245	19 57·8	19·2		20	18 11 39	265	26 54·9	2·6	
22	15 41 47	246	S. 20 17·0	18·9		22	18 16 04	265	S. 26 57·5	2·1	
			Friday 26						**Monday 29**		
00	15 45 53	246	S. 20 35·9	18·4		00	18 20 29	266	S. 26 59·6	1·6	
02	15 49 59	248	20 54·3	18·1		02	18 24 55	265	27 01·2	1·1	
04	15 54 07	248	21 12·4	17·6		04	18 29 20	266	27 02·3	0·6	
06	15 58 15	249	21 30·0	17·3		06	18 33 46	266	27 02·9	0·0	
08	16 02 24	249	21 47·3	16·8		08	18 38 12	265	27 02·9	0·4	
10	16 06 33	251	22 04·1	16·5		10	18 42 37	266	27 02·5	1·0	
12	16 10 44	251	22 20·6	16·0		12	18 47 03	265	27 01·5	1·5	
14	16 14 55	251	22 36·6	15·6		14	18 51 28	266	27 00·0	2·1	
16	16 19 06	253	22 52·2	15·2		16	18 55 54	265	26 57·9	2·5	
18	16 23 19	253	23 07·4	14·7		18	19 00 19	266	26 55·4	3·1	
20	16 27 32	254	23 22·1	14·3		20	19 04 45	265	26 52·3	3·6	
22	16 31 46	254	S. 23 36·4	13·9		22	19 09 10	265	S. 26 48·7	4·1	
			Saturday 27						**Tuesday 30**		
00	16 36 00	255	S. 23 50·3	13·4		00	19 13 35	264	S. 26 44·6	4·6	
02	16 40 15	256	24 03·7	13·0		02	19 17 59	265	26 40·0	5·1	
04	16 44 31	257	24 16·7	12·5		04	19 22 24	264	26 34·9	5·7	
06	16 48 48	257	24 29·2	12·0		06	19 26 48	264	26 29·2	6·1	
08	16 53 05	258	24 41·2	11·6		08	19 31 12	263	26 23·1	6·7	
10	16 57 23	258	24 52·8	11·1		10	19 35 35	263	26 16·4	7·1	
12	17 01 41	259	25 03·9	10·6		12	19 39 58	263	26 09·3	7·7	
14	17 06 00	259	25 14·5	10·2		14	19 44 21	263	26 01·6	8·1	
16	17 10 19	260	25 24·7	9·7		16	19 48 44	262	25 53·5	8·7	
18	17 14 39	261	25 34·4	9·1		18	19 53 06	261	25 44·8	9·2	
20	17 19 00	261	25 43·5	8·7		20	19 57 27	261	25 35·6	9·6	
22	17 23 21	262	25 52·2	8·2		22	20 01 48	261	25 26·0	10·1	
24	17 27 43		S. 26 00·4			24	20 06 09		S. 25 15·9		

MAY, 1929.

Star's Name.	Mag.	Right Ascension.	Declination.
		h. m. s.	° ′
α Phœnicis,	2·4	00 22 46	S. 42 41·3
α Ursæ Minoris, *Polaris*	2·1	01 35 07	N. 88 55·3
α Eridani, *Achernar*	0·6	01 35 03	S. 57 35·6
γ Andromedæ,	2·2	01 59 30	N. 41 59·3
α Persei, *Mirfak*	1·9	03 19 13	N. 49 36·6
α Tauri, *Aldebaran*	1·1	04 31 50	N. 16 22·1
β Orionis, *Rigel*	0·3	05 11 06	S. 8 16·9
α Aurigæ, *Capella*	0·2	05 11 25	N. 45 55·8
γ Orionis, *Bellatrix*	1·7	05 21 18	N. 6 17·2
β Tauri, *Nath*	1·8	05 21 47	N. 28 33·0
ε Orionis,	1·8	05 32 36	S. 1 14·7
ζ Orionis,	1·9	05 37 10	S. 1 58·7
α Orionis, *Betelguese*	0·5-1·1	05 51 19	N. 7 23·8
β Aurigæ,	2·1	05 54 18	N. 44 56·7
β Canis Majoris, *Mirzam*	2·0	06 19 33	S. 17 55·2
α Argus, *Canopus*	−0·9	06 22 21	S. 52 39·5
γ Geminorum, *Alhena*	1·9	06 33 36	N. 16 27·8
α Canis Majoris, *Sirius*	−1·6	06 42 00	S. 16 37·1
ε Canis Majoris,	1·6	06 55 49	S. 28 52·6
δ Canis Majoris,	2·0	07 05 29	S. 26 16·8
α Geminorum, *Castor*	1·6	07 30 04	N. 32 02·9
α Canis Minoris, *Procyon*	0·5	07 35 35	N. 5 24·5
β Geminorum, *Pollux*	1·2	07 40 58	N. 28 12·1
γ Argus,	1·9	08 07 20	S. 47 07·8
ε Argus,	1·7	08 21 02	S. 59 17·1
δ Argus,	2·0	08 42 44	S. 54 27·1
β Argus,	1·8	09 12 24	S. 69 25·8
α Hydræ, *Alphard*	2·2	09 24 06	S. 8 21·1
α Leonis, *Regulus*	1·3	10 04 36	N. 12 18·9
γ Leonis,	2·3	10 16 04	N. 20 12·1
β Ursæ Majoris,	2·4	10 57 36	N. 56 46·0
α Ursæ Majoris, *Dubhe*	2·0	10 59 23	N. 62 08·3
β Leonis, *Denebola*	2·2	11 45 27	N. 14 58·1
α Crucis,	1·1	12 22 39	S. 62 42·7
γ Crucis,	1·6	12 27 14	S. 56 43·3
β Crucis,	1·5	12 43 35	S. 59 18·4
ε Ursæ Majoris, *Alioth*	1·7	12 50 57	N. 56 20·8
ζ Ursæ Majoris, *Mizar*	2·2	13 21 07	N. 55 17·8
α Virginis, *Spica*	1·2	13 21 28	S. 10 47·6
η Ursæ Majoris, *Benetnasch*	1·9	13 44 47	N. 49 40·0
β Centauri,	0·9	13 58 50	S. 60 02·1
α Bootis, *Arcturus*	0·2	14 12 27	N. 19 33·0
α Centauri,	0·1	14 34 48	S. 60 32·8
β Ursæ Minoris, *Kochab*	2·2	14 50 59	N. 74 26·7
α Coronæ Borealis, *Alphacca*	2·3	15 31 43	N. 26 57·0
α Scorpii, *Antares*	1·2	16 25 05	S. 26 16·7
α Trianguli Australis,	1·9	16 41 12	S. 68 54·0
λ Scorpii,	1·7	17 28 49	S. 37 03·3
α Ophiuchi,	2·1	17 31 40	N. 12 36·4
θ Scorpii,	2·0	17 32 15	S. 42 57·3
ε Sagittarii,	2·0	18 19 29	S. 34 25·2
α Lyræ, *Vega*	0·1	18 34 33	N. 38 42·7
σ Sagittari,	2·1	18 50 53	S. 26 23·2
α Aquilæ, *Altair*	0·9	19 47 20	N. 8 40·6
α Pavonis,	2·1	20 20 04	S. 56 57·7
α Cygni, *Deneb*	1·3	20 39 01	N. 45 01·2
α Gruis,	2·2	22 03 47	S. 47 18·2
β Gruis,	2·2	22 38 26	S. 47 15·2
α Piscis Australis, *Fomalhaut*	1·3	22 53 44	S 29 59·8

MAY, 1929.

Date.		Day of Year.	Sun's Semi-diameter.	THE MOON'S								
				Semi-diameter.	Horizontal Parallax.	Meridian Passage.						Age at 0h.
						Upper.		Diff.	Lower.		Diff.	
			′	′	′	h.	m.	m.	h.	m.	m.	d.
Wed.	1	121	15·9	14·9	54·5	05	44	49	18	08	48	21·1
Thur.	2	122	15·9	15·0	55·0	06	33	47	18	56	47	22·1
Fri.	3	123	15·9	15·1	55·5	07	20	46	19	43	46	23·1
Sat.	4	124	15·9	15·3	56·3	08	06	46	20	29	45	24·1
Sun.	5	125	15·9	15·6	57·1	08	52	46	21	14	47	25·1
Mon.	6	126	15·9	15·8	58·0	09	38	47	22	01	49	26·1
Tues.	7	127	15·9	16·0	58·9	10	25	51	22	50	52	27·1
Wed.	8	128	15·9	16·3	59·7	11	16	54	23	42	57	28·1
Thur.	9	129	15·9	16·4	60·3	12	10	60	*	*		29·1
Fri.	10	130	15·9	16·5	60·7	13	10	63	00	39	62	0·7
Sat.	11	131	15·9	16·6	60·8	14	13	65	01	41	64	1·7
Sun.	12	132	15·9	16·5	60·6	15	18	64	02	45	65	2·7
Mon.	13	133	15·9	16·4	60·2	16	22	60	03	50	62	3·7
Tues.	14	134	15·8	16·2	59·6	17	22	55	04	52	58	4·7
Wed.	15	135	15·8	16·1	58·9	18	17	50	05	50	52	5·7
Thur.	16	136	15·8	15·9	58·2	19	07	46	06	42	49	6·7
Fri.	17	137	15·8	15·7	57·5	19	53	44	07	31	45	7·7
Sat.	18	138	15·8	15·5	56·9	20	37	43	08	16	43	8·7
Sun.	19	139	15·8	15·3	56·3	21	20	42	08	59	42	9·7
Mon.	20	140	15·8	15·2	55·7	22	02	44	09	41	43	10·7
Tues.	21	141	15·8	15·1	55·3	22	46	45	10	24	44	11·7
Wed.	22	142	15·8	15·0	54·9	23	31	47	11	08	46	12·7
Thur.	23	143	15·8	14·9	54·6	*	*		11	54	48	13·7
Fri.	24	144	15·8	14·8	54·3	00	18	49	12	42	50	14·7
Sat.	25	145	15·8	14·7	54·1	01	07	50	13	32	50	15·7
Sun.	26	146	15·8	14·7	54·0	01	57	51	14	22	51	16·7
Mon.	27	147	15·8	14·7	54·0	02	48	50	15	13	50	17·7
Tues.	28	148	15·8	14·8	54·2	03	38	49	16	03	48	18·7
Wed.	29	149	15·8	14·8	54·5	04	27	47	16	51	46	19·7
Thur.	30	150	15·8	15·0	54·9	05	14	46	17	37	45	20·7
Fri.	31	151	15·8	15·1	55·5	06	00	44	18	22	44	21·7
Sat.	32	152	15·8	15·3	56·2	06	44		19	06		22·7

MAY. 1929.

THE SUN.

G.M.T.	Wednesday 8									Sunday 12								
	R.			Dec.			*E.*			*R.*			Dec.			*E.*		
h.	h.	m.	s.	°	′		h.	m.	s.	h.	m.	s.	°	′		h.	m.	s.
00	15	01	20·1	N. 16	53·7		12	03	34·4	15	17	06·4	N. 17	57·3		12	03	45·4
02	15	01	39·9		16	55·0	12	03	34·7	15	17	26·1		17	58·6	12	03	45·5
04	15	01	59·6		16	56·4	12	03	35·1	15	17	45·8		17	59·9	12	03	45·6
06	15	02	19·3		16	57·8	12	03	35·4	15	18	05·5		18	01·1	12	03	45·7
08	15	02	39·0		16	59·1	12	03	35·7	15	18	25·2		18	02·4	12	03	45·9
10	15	02	58·7		17	00·5	12	03	36·0	15	18	44·9		18	03·7	12	03	46·0
12	15	03	18·4		17	01·9	12	03	36·3	15	19	04·7		18	05·0	12	03	46·1
14	15	03	38·1		17	03·2	12	03	36·6	15	19	24·4		18	06·2	12	03	46·2
16	15	03	57·9		17	04·6	12	03	36·9	15	19	44·1		18	07·5	12	03	46·3
18	15	04	17·6		17	05·9	12	03	37·2	15	20	03·8		18	08·7	12	03	46·4
20	15	04	37·3		17	07·3	12	03	37·5	15	20	23·5		18	10·0	12	03	46·5
22	15	04	57·0		17	08·7	12	03	37·7	15	20	43·2		18	11·3	12	03	46·6
	Thursday 9									Wednesday 15								
00	15	05	16·7	N. 17	10·0		12	03	38·0	15	28	56·0	N. 18	41·9		12	03	47·6
02	15	05	36·4		17	11·4	12	03	38·3	15	29	15·8		18	43·1	12	03	47·6
04	15	05	56·1		17	12·7	12	03	38·5	15	29	35·5		18	44·3	12	03	47·6
06	15	06	15·8		17	14·0	12	03	38·8	15	29	55·2		18	45·5	12	03	47·6
08	15	06	35·6		17	15·4	12	03	39·1	15	30	14·9		18	46·7	12	03	47·6
10	15	06	55·3		17	16·7	12	03	39·3	15	30	34·6		18	47·9	12	03	47·6
12	15	07	15·0		17	18·1	12	03	39·6	15	30	54·3		18	49·1	12	03	47·5
14	15	07	34·7		17	19·4	12	03	39·8	15	31	14·0		18	50·3	12	03	47·5
16	15	07	54·4		17	20·7	12	03	40·1	15	31	33·7		18	51·5	12	03	47·5
18	15	08	14·1		17	22·1	12	03	40·3	15	31	53·5		18	52·6	12	03	47·4
20	15	08	33·8		17	23·4	12	03	40·6	15	32	13·2		18	53·8	12	03	47·4
22	15	08	53·5		17	24·8	12	03	40·8	15	32	32·9		18	55·0	12	03	47·3
	Friday 10									Monday 20								
00	15	09	13·3	N. 17	26·1		12	03	41·0	15	58	38·8	N. 19	49·9		12	03	40·4
02	15	09	33·0		17	27·4	12	03	41·3	15	48	58·5		19	50·9	12	03	40·2
04	15	09	52·7		17	28·7	12	03	41·5	15	49	18·3		19	52·0	12	03	40·0
06	15	10	12·4		17	30·0	12	03	41·7	15	49	38·0		19	53·1	12	03	39·7
08	15	10	32·1		17	31·4	12	03	41·9	15	49	57·7		19	54·1	12	03	39·5
10	15	10	51·8		17	32·7	12	03	42·1	15	50	17·4		19	55·2	12	03	39·2
12	15	11	11·5		17	34·0	12	03	42·3	15	50	37·1		19	56·2	12	03	39·0
14	15	11	31·3		17	35·3	12	03	42·5	15	50	56·8		19	57·3	12	03	38·7
16	15	11	51·0		17	36·6	12	03	42·7	15	51	16·5		19	58·3	12	03	38·5
18	15	12	10·7		17	37·9	12	03	42·9	15	51	36·2		19	59·4	12	03	38·2
20	15	12	30·4		17	39·2	12	03	43·1	15	51	56·0		20	00·4	12	03	37·9
22	15	12	50·1		17	40·5	12	03	43·3	15	52	15·7		20	01·4	12	03	37·7
	Saturday 11									Tuesday 21								
00	15	13	09·8	N. 17	41·9		12	03	43·5	15	52	35·4	N. 20	02·5		12	03	37·4
02	15	13	29·5		17	43·2	12	03	43·7	15	52	55·1		20	03·5	12	03	37·1
04	15	13	49·2		17	44·5	12	03	43·8	15	53	14·8		20	04·5	12	03	36·8
06	15	14	09·0		17	45·7	12	03	44·0	15	53	34·5		20	05·6	12	03	36·5
08	15	14	28·7		17	47·0	12	03	44·2	15	53	54·2		20	06·6	12	03	36·3
10	15	14	48·4		17	48·3	12	03	44·3	15	54	13·9		20	07·6	12	03	36·0
12	15	15	08·1		17	49·6	12	03	44·5	15	54	33·7		20	08·6	12	03	35·7
14	15	15	27·8		17	50·9	12	03	44·6	15	54	53·4		20	09·7	12	03	35·4
16	15	15	47·5		17	52·2	12	03	44·8	15	55	13·1		20	10·7	12	03	35·1
18	15	16	07·2		17	53·5	12	03	44·9	15	55	32·8		20	11·7	12	03	34·7
20	15	16	26·9		17	54·8	12	03	45·1	15	55	52·5		20	12·7	12	03	34·4
22	15	16	46·7	N. 17	56·1		12	03	45·2	15	56	12·2	N. 20	13·7		12	03	34·1

R. is the Right Ascension of the Mean Sun ± 12 hours. *E.* is 12 hours minus the Equation of Time.

JUNE, 1929.

Star's Name.	Mag.	Right Ascension.	Declination.
		h. m. s.	° ′
α Andromedæ, ... *Alpheratz*	2·2	00 04 43	N. 28 41·8
α Phœnicis, ...	2·4	00 22 47	S. 42 41·2
α Cassiopeiæ, ... *Schedar*	2·1-2·6	00 36 28	N. 56 08·7
β Ceti, ...	2·2	00 40 02	S. 18 22·4
β Andromedæ, ...	2·4	01 05 45	N. 35 14·6
α Ursæ Minoris, ... *Polaris*	2·1	01 35 34	N. 88 55·2
α Eridani, ... *Achernar*	0·6	01 35 04	S. 57 35·5
γ Andromedæ, ...	2·2	01 59 31	N. 41 59·3
α Persei, ... *Mirfak*	1·9	03 19 13	N. 49 36·6
β Orionis, ... *Rigel*	0·3	05 11 07	S. 8 16·8
α Aurigæ, ... *Capella*	0·2	05 11 25	N. 45 55·7
α Orionis, ... *Betelguese*	0·5-1·1	05 51 19	N. 7 23·8
β Canis Majoris, ... *Mirzam*	2·0	06 19 33	S. 17 55·1
α Argus, ... *Canopus*	−0·9	06 22 20	S. 52 39·3
γ Geminorum, ... *Alhena*	1·9	06 33 36	N. 16 27·8
α Canis Majoris, ... *Sirius*	−1·6	06 42 00	S. 16 37·0
ε Canis Majoris, ...	1·6	06 55 49	S. 28 52·4
δ Canis Majoris, ...	2·0	07 05 29	S. 26 16·7
α Geminorum, ... *Castor*	1·6	07 30 04	N. 32 02·9
α Canis Minoris, ... *Procyon*	0·5	07 35 35	N. 5 24·6
β Geminorum, ... *Pollux*	1·2	07 40 58	N. 28 12·1
γ Argus, ...	1·9	08 07 19	S. 47 07·7
ε Argus, ...	1·7	08 21 01	S. 59 17·0
δ Argus, ...	2·0	08 42 43	S. 54 27·0
β Argus, ...	1·8	09 12 23	S. 69 25·7
α Hydræ, ... *Alphard*	2·2	09 24 06	S. 8 21·0
α Leonis, ... *Regulus*	1·3	10 04 36	N. 12 18·9
γ Leonis, ...	2·3	10 16 04	N. 20 12·2
β Ursæ Majoris, ...	2·4	10 57 35	N. 56 46·0
α Ursæ Majoris, ... *Dubhe*	2·0	10 59 22	N. 62 08·3
β Leonis, ... *Denebola*	2·2	11 45 27	N. 14 58·2
α Crucis, ...	1·1	12 22 38	S. 62 42·7
γ Crucis, ...	1·6	12 27 13	S. 56 43·3
β Crucis, ...	1·5	12 43 34	S. 59 18·4
ε Ursæ Majoris, ... *Alioth*	1·7	12 50 56	N. 56 20·9
ζ Ursæ Majoris, ... *Mizar*	2·2	13 21 06	N. 55 17·9
α Virginis, ... *Spica*	1·2	13 21 28	S. 10 47·6
η Ursæ Majoris, ... *Benetnasch*	1·9	13 44 47	N. 49 40·2
β Centauri, ...	0·9	13 58 49	S. 60 02·2
α Bootis, ... *Arcturus*	0·2	14 12 27	N. 19 33·0
α Centauri, ...	0·1	14 34 48	S. 60 32·9
β Ursæ Minoris, ... *Kochab*	2·2	14 50 58	N. 74 26·9
α Coronæ Borealis, . . . *Alphacca*	2·3	15 31 43	N. 26 57·1
α Scorpii, ... *Antares*	1·2	16 25 05	S. 26 16·7
α Trianguli Australis, ...	1·9	16 41 12	S. 68 54·2
λ Scorpii, ...	1·7	17 28 50	S. 37 03·3
α Ophiuchi, ...	2·1	17 31 40	N. 12 36·5
θ Scorpii, ...	2·0	17 32 16	S. 42 57·4
ε Sagittarii, ...	2·0	18 19 30	S. 34 25·3
α Lyræ, ... *Vega*	0·1	18 34 34	N. 38 42·9
σ Sagittarii, ...	2·1	18 50 54	S. 26 23·2
α Aquilæ, ... *Altair*	0·9	19 47 21	N. 8 40·7
α Pavonis, ...	2·1	20 20 06	S. 56 57·7
α Cygni, ... *Deneb*	1·3	20 39 02	N. 45 01·4
α Gruis, ...	2·2	22 03 48	S. 47 18·1
β Gruis, ...	2·2	22 38 28	S. 47 15·1
α Piscis Australis, . . *Fomalhaut*	1·3	22 53 45	S. 29 59·7

JUNE, 1929.

Date.		Day of Year.	Sun's Semi-diameter.	THE MOON'S								
				Semi-diameter.	Horizontal Parallax.	Meridian Passage.						Age at 0h.
						Upper.		Diff.	Lower.		Diff.	
			′	′	′	h.	m.	m.	h.	m.	m.	d.
Sat.	1	152	15·8	15·3	56·2	06	44		19	06		22·7
								44			45	
Sun.	2	153	15·8	15·5	57·0	07	28		19	51		23·7
								46			46	
Mon.	3	154	15·8	15·8	58·0	08	14		20	37		24·7
								48			50	
Tues.	4	155	15·8	16·1	58·9	09	02		21	27		25·7
								52			54	
Wed.	5	156	15·8	16·3	59·8	09	54		22	21		26·7
								56			60	
Thur.	6	157	15·8	16·5	60·6	10	50		23	21		27·7
								62			64	
Fri.	7	158	15·8	16·6	61·1	11	52		*	*		28·7
								66				
Sat.	8	159	15·8	16·7	61·3	12	58		00	25		0·4
								67			67	
Sun.	9	160	15·8	16·7	61·2	14	05		01	32		1·4
								64			66	
Mon.	10	161	15·8	16·6	60·7	15	09		02	38		2·4
								59			62	
Tues.	11	162	15·8	16·4	60·1	16	08		03	40		3·4
								54			56	
Wed.	12	163	15·8	16·2	59·3	17	02		04	36		4·4
								49			51	
Thur.	13	164	15·8	15·9	58·4	17	51		05	27		5·4
								45			47	
Fri.	14	165	15·8	15·7	57·5	18	36		06	14		6·4
								43			44	
Sat.	15	166	15·8	15·5	56·7	19	19		06	58		7·4
								43			43	
Sun.	16	167	15·8	15·3	56·0	20	02		07	41		8·4
								43			42	
Mon.	17	168	15·8	15·1	55·4	20	45		08	23		9·4
								44			43	
Tues.	18	169	15·8	15·0	54·9	21	29		09	06		10·4
								46			45	
Wed.	19	170	15·8	14·9	54·5	22	15		09	51		11·4
								48			47	
Thur.	20	171	15·8	14·8	54·3	23	03		10	38		12·4
								50			50	
Fri.	21	172	15·8	14·7	54·1	23	53		11	28		13·4
								51			50	
Sat.	22	173	15·8	14·7	54·0	*	*		12	18		14·4
											51	
Sun.	23	174	15·8	14·7	54·0	00	44		13	09		15·4
								50			50	
Mon.	24	175	15·8	14·7	54·1	01	34		13	59		16·4
								50			49	
Tues.	25	176	15·8	14·8	54·3	02	24		14	48		17·4
								47			46	
Wed.	26	177	15·8	14·9	54·5	03	11		15	34		18·4
								46			45	
Thur.	27	178	15·8	15·0	55·0	03	57		16	19		19·4
								44			43	
Fri.	28	179	15·8	15·1	55·5	04	41		17	02		20·4
								43			44	
Sat.	29	180	15·8	15·3	56·1	05	24		17	46		21·4
								43			44	
Sun.	30	181	15·8	15·5	56·9	06	07		18	30		22·4
								46			46	
Mon.	31	182	15·8	15·7	57·8	06	53		19	16		23·4

JUNE, 1920.

THE SUN.

G.M.T.	Thursday 13									Wednesday 19								
	R.			Dec.		*E.*				*R.*			Dec.		*E.*			
h.	h.	m.	s.	°	′	h.	m.	s.		h.	m.	s.	°	′	h.	m.	s.	
00	17	23	16·2	N. 23	10·6	12	00	19·9		17	46	55·6	N. 23	25·2	11	59	03·5	
02	17	23	35·9	23	10·9	12	00	18·8		17	47	15·3	23	25·3	11	59	02·4	
04	17	23	55·6	23	11·2	12	00	17·8		17	47	35·0	23	25·4	11	59	01·3	
06	17	24	15·4	23	11·5	12	00	16·8		17	47	54·7	23	25·5	11	59	00·2	
08	17	24	35·1	23	11·8	12	00	15·7		17	48	14·4	23	25·6	11	58	59·2	
10	17	24	54·8	23	12·1	12	00	14·7		17	48	34·1	23	25·7	11	58	58·1	
12	17	25	14·5	23	12·4	12	00	13·6		17	48	53·8	23	25·8	11	58	57·0	
14	17	25	34·2	23	12·7	12	00	12·6		17	49	13·6	23	25·9	11	58	55·9	
16	17	25	53·9	23	12·9	12	00	11·6		17	49	33·3	23	25·9	11	58	54·8	
18	17	26	13·6	23	13·2	12	00	10·5		17	49	53·0	23	26·0	11	58	53·8	
20	17	26	33·3	23	13·5	12	00	09·5		17	50	12·7	23	26·1	11	58	52·7	
22	17	26	53·1	23	13·8	12	00	08·4		17	50	32·4	23	26·2	11	58	51·6	
	Friday 14									Friday 21								
00	17	27	12·8	N. 23	14·1	12	00	07·4		17	54	48·7	N. 23	26·8	11	58	37·6	
02	17	27	32·5	23	14·3	12	00	06·4		17	55	08·4	23	26·8	11	58	36·5	
04	17	27	52·2	23	14·6	12	00	05·3		17	55	28·1	23	26·9	11	58	35·4	
06	17	28	11·9	23	14·9	12	00	04·3		17	55	47·8	23	26·9	11	58	34·3	
08	17	28	31·6	23	15·1	12	00	03·2		17	56	07·5	23	26·9	11	58	33·2	
10	17	28	51·3	23	15·4	12	00	02·2		17	56	27·2	23	26·9	11	58	32·2	
12	17	29	11·1	23	15·6	12	00	01·1		17	56	47·0	23	27·0	11	58	31·1	
14	17	29	30·8	23	15·9	12	00	00·1		17	57	06·7	23	27·0	11	58	30·0	
16	17	29	50·5	23	16·1	11	59	59·0		17	57	26·4	23	27·0	11	58	28·9	
18	17	30	10·2	23	16·4	11	59	58·0		17	57	46·1	23	27·0	11	58	27·8	
20	17	30	29·9	23	16·6	11	59	56·9		17	58	05·8	23	27·0	11	58	26·8	
22	17	30	49·6	23	16·9	11	59	55·8		17	58	25·5	23	27·0	11	58	25·7	
	Saturday 15									Saturday 22								
00	17	31	09·3	N. 23	17·1	11	59	54·8		17	58	45·2	N. 23	27·0	11	58	24·6	
02	17	31	29·0	23	17·4	11	59	53·7		17	59	05·0	23	27·0	11	58	23·5	
04	17	31	48·8	23	17·6	11	59	52·7		17	59	24·7	23	27·0	11	58	22·5	
06	17	32	08·5	23	17·8	11	59	51·6		17	59	44·4	23	27·0	11	58	21·4	
08	17	32	28·2	23	18·0	11	59	50·6		18	00	04·1	23	26·9	11	58	20·3	
10	17	32	47·9	23	18·3	11	59	49·5		18	00	23·8	23	26·9	11	58	19·2	
12	17	33	07·6	23	18·5	11	59	48·5		18	00	43·5	23	26·9	11	58	18·2	
14	17	33	27·3	23	18·7	11	59	47·4		18	01	03·2	23	26·9	11	58	17·1	
16	17	33	47·0	23	18·9	11	59	46·3		18	01	22·9	23	26·9	11	58	16·0	
18	17	34	06·7	23	19·1	11	59	45·3		18	01	42·7	23	26·8	11	58	14·9	
20	17	34	26·5	23	19·3	11	59	44·2		18	02	02·4	23	26·8	11	58	13·8	
22	17	34	46·2	N. 23	19·6	11	59	43·1		18	02	22·1	N. 23	26·8	11	58	12·8	

R. is the Right Ascension of the Mean Sun ± 12 hours. *E.* is 12 hours minus the Equation of Time.

JUNE, 1929.

THE SUN.

G.M.T.	Sunday 23									Wednesday 26								
	R.			Dec.		*E.*				*R.*			Dec.		*E.*			
h.	h.	m.	s.	°	′	h.	m.	s.		h.	m.	s.	°	′	h.	m.	s.	
00	18	02	41·8	N. 23	26·7	11	58	11·7		18	14	31·5	N. 23	23·5	11	57	33·3	
02	18	03	01·5	23	26·7	11	58	10·6		18	14	51·2	23	23·4	11	57	32·3	
04	18	03	21·2	23	26·7	11	58	09·6		18	15	10·9	23	23·2	11	57	31·2	
06	18	03	40·9	23	26·6	11	58	08·5		18	15	30·6	23	23·1	11	57	30·2	
08	18	04	00·7	23	26·6	11	58	07·4		18	15	50·3	23	23·0	11	57	29·1	
10	18	04	20·4	23	26·5	11	58	06·3		18	16	10·0	23	22·8	11	57	28·1	
12	18	04	40·1	23	26·5	11	58	05·3		18	16	29·8	23	22·6	11	57	27·0	
14	18	04	59·8	23	26·4	11	58	04·2		18	16	49·5	23	22·5	11	57	26·0	
16	18	05	19·5	23	26·4	11	58	03·1		18	17	09·2	23	22·3	11	57	24·9	
18	18	05	39·2	23	26·3	11	58	02·0		18	17	28·9	23	22·2	11	57	23·9	
20	18	05	58·9	23	26·2	11	58	01·0		18	17	48·6	23	22·0	11	57	22·8	
22	18	06	18·6	23	26·2	11	57	59·9		18	18	08·3	23	21·8	11	57	21·8	
	Monday 24									Thursday 27								
00	18	06	38·4	N. 23	26·1	11	57	58·8		18	18	28·0	N. 23	21·6	11	57	20·7	
02	18	06	58·1	23	26·0	11	57	57·8		18	18	47·7	23	21·5	11	57	19·7	
04	18	07	17·8	23	25·9	11	57	56·7		18	19	07·5	23	21·3	11	57	18·7	
06	18	07	37·5	23	25·9	11	57	55·6		18	19	27·2	23	21·1	11	57	17·6	
08	18	07	57·2	23	25·8	11	57	54·6		18	19	46·9	23	20·9	11	57	16·6	
10	18	08	16·9	23	25·7	11	57	53·5		18	20	06·6	23	20·7	11	57	15·5	
12	18	08	36·6	23	25·6	11	57	52·4		18	20	26·3	23	20·6	11	57	14·5	
14	18	08	56·4	23	25·5	11	57	51·4		18	20	46·0	23	20·4	11	57	13·5	
16	18	09	16·1	23	25·4	11	57	50·3		18	21	05·7	23	20·2	11	57	12·4	
18	18	09	35·8	23	25·3	11	57	49·2		18	21	25·4	23	20·0	11	57	11·4	
20	18	09	55·5	23	25·2	11	57	48·2		18	21	45·2	23	19·8	11	57	10·3	
22	18	10	15·2	23	25·1	11	57	47·1		18	22	04·9	23	19·6	11	57	09·3	
	Tuesday 25									Friday 28								
00	18	10	34·9	N. 23	25·0	11	57	46·0		18	22	24·6	N. 23	19·4	11	57	08·3	
02	18	10	54·6	23	24·9	11	57	45·0		18	22	44·3	23	19·1	11	57	07·2	
04	18	11	14·3	23	24·8	11	57	43·9		18	23	04·0	23	18·9	11	57	06·2	
06	18	11	34·1	23	24·7	11	57	42·8		18	23	23·7	23	18·7	11	57	05·2	
08	18	11	53·8	23	24·6	11	57	41·8		18	23	43·4	23	18·5	11	57	04·2	
10	18	12	13·5	23	24·4	11	57	40·7		18	24	03·2	23	18·3	11	57	03·1	
12	18	12	33·2	23	24·3	11	57	39·7		18	24	22·9	23	18·1	11	57	02·1	
14	18	12	52·9	23	24·2	11	57	38·6		18	24	42·6	23	17·8	11	57	01·1	
16	18	13	12·6	23	24·1	11	57	37·5		18	25	02·3	23	17·6	11	57	00·1	
18	18	13	32·3	23	23·9	11	57	36·5		18	25	22·0	23	17·3	11	56	59·0	
20	18	13	52·0	23	23·8	11	57	35·4		18	25	41·7	23	17·1	11	56	58·0	
22	18	14	11·8	N. 23	23·7	11	57	34·4		18	26	01·4	N. 23	16·9	11	56	57·0	

R. is the Right Ascension of the Mean Sun $\pm$ 12 hours. *E.* is 12 hours minus the Equation of Time.

JUNE, 1929.

MOON'S RIGHT ASCENSION AND DECLINATION.

G.M.T.	R.A.				Dec.			
h.	h.	m.	s.	s.	°	′	′
Monday 17							
00	13	47	37	227	S. 8	56·6	26·7
02	13	51	24	226	9	23·3	26·5
04	13	55	10	227	9	49·8	26·3
06	13	58	57	227	10	16·1	26·1
08	14	02	44	228	10	42·2	25·9
10	14	06	32	228	11	08·1	25·6
12	14	10	20	228	11	33·7	25·5
14	14	14	08	229	11	59·2	25·2
16	14	17	57	229	12	24·4	25·0
18	14	21	46	229	12	49·4	24·8
20	14	25	35	230	13	14·2	24·5
22	14	29	25	331	S. 13	38·7	24·2
Tuesday 18							
00	14	33	16	231	S. 14	02·9	24·0
02	14	37	07	232	14	26·9	23·8
04	14	40	59	232	14	50·7	23·5
06	14	44	51	233	15	14·2	23·2
08	14	48	44	234	15	37·4	22·9
10	14	52	38	234	16	00·3	22·6
12	14	56	32	235	16	22·9	22·3
14	15	00	27	235	16	45·2	22·1
16	15	04	22	237	17	07·3	21·7
18	15	08	19	237	17	29·0	21·4
20	15	12	16	237	17	50·4	21·1
22	15	16	13	239	S. 18	11·5	20·8
Wednesday 19							
00	15	20	12	239	S. 18	32·3	20·4
02	15	24	11	240	18	52·7	20·1
04	15	28	11	241	19	12·8	19·8
06	15	32	12	241	19	32·6	19·4
08	15	36	13	243	19	52·0	19·0
10	15	40	16	243	20	11·0	18·7
12	15	44	19	244	20	29·7	18·3
14	15	48	23	245	20	48·0	18·0
16	15	52	28	245	21	06·0	17·6
18	15	56	33	247	21	23·6	17·2
20	16	00	40	247	21	40·8	16·7
22	16	04	47	248	S. 21	57·5	16·4
Thursday 20							
00	16	08	55	249	S. 22	13·9	16·0
02	16	13	04	249	22	29·9	15·6
04	16	17	13	251	22	45·5	15·2
06	16	21	24	251	23	00·7	14·7
08	16	25	35	252	23	15·4	14·3
10	16	29	47	253	23	29·7	13·9
12	16	34	00	253	23	43·6	13·5
14	16	38	13	255	23	57·1	13·0
16	16	42	28	255	24	10·1	12·6
18	16	46	43	256	24	22·7	12·1
20	16	50	59	256	24	34·8	11·6
22	16	55	15	257	24	46·4	11·2
24	16	59	32		S. 24	57·6	

G.M.T.	R.A.				Dec.			
h.	h.	m.	s.	s.	°	′	′
Friday 21							
00	16	59	32	258	S. 24	57·6	10·8
02	17	03	50	259	25	08·4	10·2
04	17	08	09	259	25	18·6	9·8
06	17	12	28	260	25	28·4	9·3
08	17	16	48	260	25	37·7	8·8
10	17	21	08	261	25	46·5	8·3
12	17	25	29	262	25	54·8	7·9
14	17	29	51	262	26	02·7	7·3
16	17	34	13	262	26	10·0	6·9
18	17	38	35	263	26	16·9	6·3
20	17	42	58	263	26	23·2	5·9
22	17	47	21	264	S. 26	29·1	5·3
Saturday 22							
00	17	51	45	264	S. 26	34·4	4·8
02	17	56	09	264	26	39·2	4·4
04	18	00	33	265	26	43·6	3·8
06	18	04	58	265	26	47·4	3·3
08	18	09	23	265	26	50·7	2·7
10	18	13	48	265	26	53·4	2·3
12	18	18	13	266	26	55·7	1·8
14	18	22	39	265	26	57·5	1·2
16	18	27	04	266	26	58·7	0·7
18	18	31	30	266	26	59·4	0·2
20	18	35	56	266	26	59·6	0·4
22	18	40	22	265	S. 26	59·2	0·8
Sunday 23							
00	18	44	47	266	S. 26	58·4	1·4
02	18	49	13	265	26	57·0	1·9
04	18	53	38	266	26	55·1	2·4
06	18	58	04	265	26	52·7	2·9
08	19	02	29	265	26	49·8	3·5
10	19	06	54	265	26	46·3	4·0
12	19	11	19	264	26	42·3	4·4
14	19	15	43	264	26	37·9	5·0
16	19	20	07	264	26	32·9	5·5
18	19	24	31	263	26	27·4	6·0
20	19	28	54	263	26	21·4	6·5
22	19	33	17	263	S. 26	14·9	7·0
Monday 24							
00	19	37	40	262	S. 26	07·9	7·5
02	19	42	02	262	26	00·4	8·0
04	19	46	24	261	25	52·4	8·5
06	19	50	45	261	25	43·9	9·0
08	19	55	06	260	25	34·9	9·5
10	19	59	26	259	25	25·4	9·9
12	20	03	45	259	25	15·5	10·4
14	20	08	04	258	25	05·1	10·9
16	20	12	22	257	24	54·2	11·4
18	20	16	39	257	24	42·8	11·8
20	20	20	56	257	24	31·0	12·3
22	20	25	13	255	24	18·7	12·7
24	20	29	28		S. 24	06·0	

AUGUST. 1929.

Star's Name.	Mag.	Right Ascension.	Declination.
		h. m. s.	° ′
α Andromedæ, ... *Alpheratz*	2·2	00 04 45	N. 28 42·0
α Phœnicis, ...	2·4	00 22 50	S. 42 41·1
α Cassiopeiæ, ... *Schedar*	2·1-2·6	00 36 30	N. 56 08·9
β Ceti, ...	2·2	00 40 04	S. 18 22·2
β Andromedæ, ...	2·4	01 05 47	N. 35 14·8
α Ursæ Minoris, ... *Polaris*	2·1	01 36 44	N. 88 55·3
α Eridani. . . . . *Achernar*	0·6	01 35 07	S. 57 35·4
γ Andromedæ, ...	2·2	01 59 34	N. 41 59·5
α Arietis, ... *Hamal*	2·2	02 03 12	N. 23 07·8
α Persei, ... *Mirfak*	1·9	03 19 16	N. 49 36·6
α Tauri, ... *Aldebaran*	1·1	04 31 52	N. 16 22·2
β Orionis, ... *Rigel*	0·3	05 11 08	S. 8 16·7
α Aurigæ, ... *Capella*	0·2	05 11 27	N. 45 55·7
γ Orionis, ... *Bellatrix*	1·7	05 21 20	N. 6 17·4
β Tauri, ... *Nath*	1·8	05 21 49	N. 28 33·0
ε Orionis, ...	1·8	05 32 37	S. 1 14·5
ζ Orionis, ...	1·9	05 37 11	S. 1 58·5
α Orionis, ... *Betelguese*	0·5-1·1	05 51 20	N. 7 23·9
β Aurigæ, ...	2·1	05 54 20	N. 44 56·5
β Canis Majoris, ... *Mirzam*	2·0	06 19 34	S. 17 54·9
α Argus, ... *Canopus*	−0·9	06 22 22	S. 52 39·0
γ Geminorum, ... *Alhena*	1·9	06 33 37	N. 16 27·8
α Canis Majoris, ... *Sirius*	−1·6	06 42 01	S. 16 36·8
α Geminorum, ... *Castor*	1·6	07 30 05	N. 32 02·8
α Canis Minoris, ... *Procyon*	0·5	07 35 35	N. 5 24·6
β Geminorum, ... *Pollux*	1·2	07 40 59	N. 28 12·0
γ Argus, ...	1·9	08 07 19	S. 47 07·4
ε Argus, ...	1·7	08 21 01	S. 59 16·7
δ Argus, ...	2·0	08 42 43	S. 54 26·7
β Argus, ...	1·8	09 12 21	S. 69 25·4
β Ursæ Majoris, ...	2·4	10 57 34	N. 56 45·9
α Ursæ Majoris, ... *Dubhe*	2·0	10 59 21	N. 62 08·1
β Leonis, ... *Denebola*	2·2	11 45 27	N. 14 58·2
α Crucis, ...	1·1	12 22 37	S. 62 42·6
γ Crucis, ...	1·6	12 27 12	S. 56 43·2
β Crucis, ...	1·5	12 43 33	S. 59 18·4
ε Ursæ Majoris, ... *Alioth*	1·7	12 50 55	N. 56 20·8
ζ Ursæ Majoris, ... *Mizar*	2·2	13 21 05	N. 55 17·9
α Virginis, ... *Spica*	1·2	13 21 27	S. 10 47·6
η Ursæ Majoris, ... *Benetnasch*	1·9	13 44 45	N. 49 40·2
β Centauri, ...	0·9	13 58 48	S. 60 02·2
α Bootis, ... *Arcturus*	0·2	14 12 26	N. 19 33·1
α Centauri, ...	0·1	14 34 46	S. 60 33·0
β Ursæ Minoris, ... *Kochab*	2·2	14 50 54	N. 74 26·9
α Coronæ Borealis, . . . *Alphacca*	2·3	15 31 42	N. 26 57·2
α Scorpii, ... *Antares*	1·2	16 25 05	S. 26 16·7
α Trianguli Australis, ...	1·9	16 41 11	S. 68 54·4
λ Scorpii, ...	1·7	17 28 49	S. 37 03·4
α Ophiuchi, ...	2·1	17 31 40	N. 12 36·7
θ Scorpii, ...	2·0	17 32 15	S. 42 57·5
ε Sagittarii, ...	2·0	18 19 30	S. 34 25·3
α Lyræ, ... *Vega*	0·1	18 34 34	N. 38 43·1
σ Sagittarii, ...	2·1	18 50 54	S. 26 23·2
α Aquilæ, ... *Altair*	0·9	19 47 21	N. 8 40·9
α Pavonis, ...	2·1	20 20 07	S. 56 57·9
α Cygni, ... *Deneb*	1·3	20 39 03	N. 45 01·7
α Gruis, ...	2·2	22 03 50	S. 47 18·2
β Gruis, ...	2·2	22 38 30	S. 47 15·1
α Piscis Australis, . . *Fomalhaut*	1·3	22 53 47	S. 29 59·7

AUGUST, 1929.

Date.		Day of Year.	Sun's Semi-diameter.	THE MOON'S								
				Semi-diameter.	Horizontal Parallax.	Meridian Passage.						Age at 0h.
						Upper.		Diff.	Lower.		Diff.	
			′	′	′	h.	m.	m.	h.	m.	m.	d.
Thur.	1	213	15·8	16·3	59·9	08	17	64	20	49	65	25·1
Fri.	2	214	15·8	16·5	60·5	09	21	66	21	54	66	26·1
Sat.	3	215	15·8	16·6	60·8	10	27	65	23	00	63	27·1
Sun.	4	216	15·8	16·6	61·0	11	32	61	*	*		28·1
Mon.	5	217	15·8	16·6	60·8	12	33	56	00	03	59	29·1
Tues.	6	218	15·8	16·4	60·3	13	29	51	01	02	53	0·9
Wed.	7	219	15·8	16·2	59·6	14	20	48	01	55	49	1·9
Thur.	8	220	15·8	16·0	58·8	15	08	45	02	44	47	2·9
Fri.	9	221	15·8	15·8	57·8	15	53	45	03	31	44	3·9
Sat.	10	222	15·8	15·5	56·9	16	38	44	04	15	45	4·9
Sun.	11	223	15·8	15·3	56·1	17	22	46	05	00	45	5·9
Mon.	12	224	15·8	15·1	55·4	18	08	47	05	45	46	6·9
Tues.	13	225	15·8	14·9	54·8	18	55	49	06	31	48	7·9
Wed.	14	226	15·8	14·8	54·4	19	44	50	07	19	50	8·9
Thur.	15	227	15·8	14·8	54·2	20	34	51	08	09	51	9·9
Fri.	16	228	15·8	14·7	54·1	21	25	51	09	00	51	10·9
Sat.	17	229	15·8	14·8	54·2	22	16	49	09	51	50	11·9
Sun.	18	230	15·8	14·8	54·3	23	05	47	10	41	48	12·9
Mon.	19	231	15·8	14·9	54·6	23	52	46	11	29	46	13·9
Tues.	20	232	15·8	15·0	54·9	*	*		12	15	45	14·9
Wed.	21	233	15·8	15·1	55·3	00	38	43	13	00	43	15·9
Thur.	22	234	15·8	15·2	55·8	01	21	44	13	43	43	16·9
Fri.	23	235	15·8	15·3	56·2	02	05	43	14	26	44	17·9
Sat.	24	236	15·8	15·5	56·8	02	48	45	15	10	46	18·9
Sun.	25	237	15·9	15·6	57·3	03	33	47	15	56	50	19·9
Mon.	26	238	15·9	15·8	57·8	04	20	52	16	46	53	20·9
Tues.	27	239	15·9	15·9	58·4	05	12	56	17	39	58	21·9
Wed.	28	240	15·9	16·1	58·9	06	08	60	18	37	63	22·9
Thur.	29	241	15·9	16·2	59·4	07	08	64	19	40	64	23·9
Fri.	30	242	15·9	16·3	59·8	08	12	63	20	44	62	24·9
Sat.	31	243	15·9	16·4	60·1	09	15	62	21	46	60	25·9
Sun.	32	244	15·9	16·4	60·2	10	17		22	46		26·9

AUGUST, 1929.

THE SUN.

G.M.T.	Thursday 1									Monday 5								
	R.			Dec.			*E.*			*R.*			Dec.			*E.*		
h.	h.	m.	s.	°	′		h.	m.	s.	h.	m.	s.	°	′		h.	m.	s.
00	20	36	27·5	N. 18	12·7		11	53	46·7	20	52	13·8	N. 17	10·8		11	54	03·6
02	20	36	47·3	18	11·5		11	53	47·0	20	52	33·5	17	09·5		11	54	04·0
04	20	37	07·0	18	10·2		11	53	47·2	20	52	53·2	17	08·1		11	54	04·5
06	20	37	26·7	18	09·0		11	53	47·5	20	53	12·9	17	06·8		11	54	04·9
08	20	37	46·4	18	07·7		11	53	47·7	20	53	32·6	17	05·4		11	54	05·4
10	20	38	06·1	18	06·5		11	53	48·0	20	53	52·3	17	04·1		11	54	05·9
12	20	38	25·8	18	05·2		11	53	48·3	20	54	12·1	17	02·7		11	54	06·3
14	20	38	45·5	18	04·0		11	53	48·6	20	54	31·8	17	01·4		11	54	06·8
16	20	39	05·3	18	02·7		11	53	48·8	20	54	51·5	17	00·0		11	54	07·3
18	20	39	25·0	18	01·4		11	53	49·1	20	55	11·2	16	58·7		11	54	07·8
20	20	39	44·7	18	00·2		11	53	49·4	20	55	30·9	16	57·3		11	54	08·3
22	20	40	04·4	17	58·9		11	53	49·7	20	55	50·6	16	56·0		11	54	08·8
	Friday 2									Tuesday 6								
00	20	40	24·1	N. 17	57·7		11	53	50·0	20	56	10·3	N. 16	54·6		11	54	09·3
02	20	40	43·8	17	56·4		11	53	50·3	20	56	30·0	16	53·2		11	54	09·8
04	20	41	03·5	17	55·1		11	53	50·6	20	56	49·8	16	51·9		11	54	10·3
06	20	41	23·2	17	53·9		11	53	50·9	20	57	09·5	16	50·5		11	54	10·8
08	20	41	43·0	17	52·6		11	53	51·3	20	57	29·2	16	49·1		11	54	11·3
10	20	42	02·7	17	51·3		11	53	51·6	20	57	48·9	16	47·8		11	54	11·8
12	20	42	22·4	17	50·0		11	53	51·9	20	58	08·6	16	46·4		11	54	12·4
14	20	42	42·1	17	48·8		11	53	52·2	20	58	28·3	16	45·0		11	54	12·9
16	20	43	01·8	17	47·5		11	53	52·6	20	58	48·0	16	43·7		11	54	13·4
18	20	43	21·5	17	46·2		11	53	52·9	20	59	07·7	16	42·3		11	54	14·0
20	20	43	41·2	17	44·9		11	53	53·2	20	59	27·5	16	40·9		11	54	14·5
22	20	44	00·9	17	43·6		11	53	53·6	20	59	47·2	16	39·5		11	54	15·0
	Saturday 3									Wednesday 7								
00	20	44	20·7	N. 17	42·3		11	53	53·9	21	00	06·9	N. 16	38·1		11	54	15·6
02	20	44	40·4	17	41·0		11	53	54·3	21	00	26·6	16	36·8		11	54	16·1
04	20	45	00·1	17	39·7		11	53	54·6	21	00	46·3	16	35·4		11	54	16·7
06	20	45	19·8	17	38·4		11	53	55·0	21	01	06·0	16	34·0		11	54	17·3
08	20	45	39·5	17	37·1		11	53	55·4	21	01	25·7	16	32·6		11	54	17·8
10	20	45	59·2	17	35·9		11	53	55·7	21	01	45·4	16	31·2		11	54	18·4
12	20	46	18·9	17	34·6		11	53	56·1	21	02	05·2	16	29·8		11	54	19·0
14	20	46	38·7	17	33·2		11	53	56·5	21	02	24·9	16	28·4		11	54	19·5
16	20	46	58·4	17	31·9		11	53	56·9	21	02	44·6	16	27·0		11	54	20·1
18	20	47	18·1	17	30·6		11	53	57·3	21	03	04·3	16	25·6		11	54	20·7
20	20	47	37·8	17	29·3		11	53	57·6	21	03	24·0	16	24·2		11	54	21·3
22	20	47	57·5	17	28·0		11	53	58·0	21	03	43·7	16	22·8		11	54	21·9
	Sunday 4									Thursday 8								
00	20	48	17·2	N. 17	26·7		11	53	58·4	21	04	03·4	N. 16	21·4		11	54	22·5
02	20	48	36·9	17	25·4		11	53	58·8	21	04	23·2	16	20·0		11	54	23·1
04	20	48	56·6	17	24·1		11	53	59·2	21	04	42·9	16	18·6		11	54	23·7
06	20	49	16·4	17	22·7		11	53	59·7	21	05	02·6	16	17·2		11	54	24·3
08	20	49	36·1	17	21·4		11	54	00·1	21	05	22·3	16	15·8		11	54	24·9
10	20	49	55·8	17	20·1		11	54	00·5	21	05	42·0	16	14·4		11	54	25·6
12	20	50	15·5	17	18·8		11	54	00·9	21	06	01·7	16	13·0		11	54	26·2
14	20	50	35·2	17	17·5		11	54	01·4	21	06	21·4	16	11·5		11	54	26·8
16	20	50	54·9	17	16·1		11	54	01·8	21	06	41·1	16	10·1		11	54	27·4
18	20	51	14·6	17	14·8		11	54	02·2	21	07	00·9	16	08·7		11	54	28·1
20	20	51	34·4	17	13·5		11	54	02·7	21	07	20·6	16	07·3		11	54	28·7
22	20	51	54·1	N. 17	12·1		11	54	03·1	21	07	40·3	N. 16	05·9		11	54	29·4

R. is the Right Ascension of the Mean Sun ± 12 hours. *E.* is 12 hours minus the Equation of Time.

AUGUST, 1929.

0h		JUPITER.						SATURN.					
		R.A.		Dec.		Meridian Passage.		R.A.		Dec.		Meridian Passage.	
		h. m. s.	s.	° ′	′	h. m.		h. m. s.	s.	° ′	′	h. m.	
Thur.	1	04 34 30	44	N. 21 13·5	1·5	07 57		17 36 16	10	S. 22 13·1	0·0	20 56	
Fri.	2	04 35 14	43	21 15·0	1·4	07 54		17 36 06	11	22 13·1	0·1	20 52	
Sat.	3	04 35 57	43	21 16·4	1·5	07 50		17 35 55	10	22 13·2	0·0	20 48	
Sun.	4	04 36 40	42	21 17·9	1·3	07 47		17 35 45	10	22 13·2	0·1	20 44	
Mon.	5	04 37 22	42	21 19·2	1·4	07 44		17 35 35	9	22 13·3	0·1	20 40	
Tues.	6	04 38 04	42	21 20·6	1·3	07 41		17 35 26	10	22 13·4	0·1	20 36	
Wed.	7	04 38 46	41	21 21·9	1·3	07 38		17 35 16	8	22 13·5	0·0	20 32	
Thur.	8	04 39 27	40	21 23·2	1·3	07 34		17 35 08	9	22 13·5	0·1	20 28	
Fri.	9	04 40 07	41	21 24·5	1·2	07 31		17 34 59	8	22 13·6	0·1	20 24	
Sat.	10	04 40 48	39	21 25·7	1·2	07 28		17 34 51	7	22 13·7	0·1	20 20	
Sun.	11	04 41 27	39	21 26·9	1·2	07 24		17 34 44	7	22 13·8	0·1	20 15	
Mon.	12	04 42 06	39	21 28·1	1·2	07 21		17 34 37	7	22 13·9	0·1	20 11	
Tues.	13	04 42 45	38	21 29·3	1·1	07 18		17 34 30	7	22 14·0	0·1	20 07	
Wed.	14	04 43 23	37	21 30·4	1·1	07 15		17 34 23	6	22 14·1	0·1	20 03	
Thur.	15	04 44 00	37	21 31·5	1·1	07 11		17 34 17	5	22 14·2	0·1	19 59	
Fri.	16	04 44 37	37	21 32·6	1·1	07 08		17 34 12	5	22 14·3	0·2	19 55	
Sat.	17	04 45 14	36	21 33·7	1·0	07 05		17 34 07	5	22 14·5	0·1	19 51	
Sun.	18	04 45 50	35	21 34·7	1·0	07 01		17 34 02	5	22 14·6	0·1	19 47	
Mon.	19	04 46 25	35	21 35·7	1·0	06 58		17 33 57	4	22 14·7	0·1	19 43	
Tues.	20	04 47 00	34	21 36·7	1·0	06 55		17 33 53	3	22 14·8	0·2	19 39	
Wed.	21	04 47 34	34	21 37·7	0·9	06 51		17 33 50	3	22 15·0	0·1	19 35	
Thur.	22	04 48 08	33	21 38·6	0·9	06 48		17 33 47	3	22 15·1	0·2	19 31	
Fri.	23	04 48 41	32	21 39·5	0·9	06 44		17 33 44	2	22 15·3	0·1	19 27	
Sat.	24	04 49 13	32	21 40·4	0·8	06 41		17 33 42	2	22 15·4	0·2	19 23	
Sun.	25	04 49 45	31	21 41·2	0·9	06 38		17 33 40	2	22 15·6	0·1	19 19	
Mon.	26	04 50 16	31	21 42·1	0·8	06 34		17 33 38	1	22 15·7	0·2	19 15	
Tues.	27	04 50 47	30	21 42·9	0·8	06 31		17 33 37	1	22 15·9	0·2	19 12	
Wed.	28	04 51 17	29	21 43·7	0·7	06 27		17 33 36	0	22 16·1	0·1	19 08	
Thur.	29	04 51 46	29	21 44·4	0·8	06 24		17 33 36	0	22 16·2	0·2	19 04	
Fri.	30	04 52 15	28	21 45·2	0·7	06 21		17 33 36	1	22 16·4	0·2	19 00	
Sat.	31	04 52 43	28	21 45·9	0·7	06 17		17 33 37	1	22 16·6	0·2	18 56	
Sun.	32	04 53 11		N. 21 46·6		06 14		17 33 38		S. 22 16·8		18 52	

SEPTEMBER, 1929.

Star's Name.	Mag.	Right Ascension.	Declination.
		h. m. s.	° ′
α Andromedæ, ... *Alpheratz*	2·2	00 04 45	N. 28 42·2
α Phœnicis, ...	2·4	00 22 50	S. 42 41·2
α Cassiopeiæ, ... *Schedar*	2·1-2·6	00 36 31	N. 56 09·1
β Ceti, ...	2·2	00 40 04	S. 18 22·2
β Andromedæ, ...	2·4	01 05 48	N. 35 14·9
α Ursæ Minoris, ... *Polaris*	2·1	01 37 10	N. 88 55·4
α Eridani, ... *Achernar*	0·6	01 35 08	S. 57 35·4
γ Andromedæ, ...	2·2	01 59 35	N. 41 59·6
α Arietis, ... *Hamal*	2·2	02 03 12	N. 23 07·9
α Persei, ... *Mirfak*	1·9	03 19 17	N. 49 36·7
α Tauri, ... *Aldebaran*	1·1	04 31 53	N. 16 22·3
β Orionis, ... *Rigel*	0·3	05 11 09	S. 8 16·6
α Aurigæ, ... *Capella*	0·2	05 11 29	N. 45 55·7
γ Orionis, ... *Bellatrix*	1·7	05 21 21	N. 6 17·5
β Tauri, ... *Nath*	1·8	05 21 50	N. 28 33·1
ε Orionis, ...	1·8	05 32 38	S. 1 14·5
ζ Orionis, ...	1·9	05 37 12	S. 1 58·4
α Orionis, ... *Betelguese*	0·5-1·1	05 51 21	N. 7 23·9
β Aurigæ, ...	2·1	05 54 21	N. 44 56·5
β Canis Majoris, ... *Mirzam*	2·0	06 19 35	S. 17 54·8
α Argus, ... *Canopus*	−0·9	06 22 23	S. 52 38·9
γ Geminorum, ... *Alhena*	1·9	06 33 38	N. 16 27·8
α Canis Majoris, ... *Sirius*	−1·6	06 42 02	S. 16 36·8
ε Canis Majoris, ...	1·6	06 55 51	S. 28 52·1
δ Canis Majoris, ...	2·0	07 05 31	S. 26 16·4
α Geminorum, ... *Castor*	1·6	07 30 06	N. 32 02·8
α Canis Minoris, ... *Procyon*	0·5	07 35 36	N. 5 24·6
β Geminorum, ... *Pollux*	1·2	07 40 59	N. 28 12·0
γ Argus, ...	1·9	08 07 20	S. 47 07·3
ε Argus, ...	1·7	08 21 02	S. 59 16·6
δ Argus, ...	2·0	08 42 43	S. 54 26·6
β Argus, ...	1·8	09 12 22	S. 69 25·3
β Ursæ Majoris, ...	2·4	10 57 34	N. 56 45·7
α Ursæ Majoris, ... *Dubhe*	2·0	10 59 22	N. 62 08·0
α Crucis, ...	1·1	12 22 36	S. 62 42·5
γ Crucis, ...	1·6	12 27 12	S. 56 43·1
β Crucis, ...	1·5	12 43 32	S. 59 18·2
ε Ursæ Majoris, ... *Alioth*	1·7	12 50 54	N. 56 20·7
ζ Ursæ Majoris, ... *Mizar*	2·2	13 21 04	N. 55 17·7
α Virginis, ... *Spica*	1·2	13 21 27	S. 10 47·6
η Ursæ Majoris, ... *Benetnasch*	1·9	13 44 45	N. 49 40·1
β Centauri, ...	0·9	13 58 47	S. 60 02·2
α Bootis, ... *Arcturus*	0·2	14 12 26	N. 19 33·1
α Centauri, ...	0·1	14 34 45	S. 60 32·9
β Ursæ Minoris, ... *Kochab*	2·2	14 50 52	N. 74 26·8
α Coronæ Borealis, . . . *Alphacca*	2·3	15 31 41	N. 26 57·2
α Scorpii, ... *Antares*	1·2	16 25 04	S. 26 16·7
α Trianguli Australis, ...	1·9	16 41 10	S. 68 54·4
γ Scorpii, ...	1·7	17 28 49	S. 37 03·4
α Ophiuchi, ...	2·1	17 31 40	N. 12 36·7
θ Scorpii, ...	2·0	17 32 15	S. 42 57·5
ε Sagittarii, ...	2·0	18 19 30	S. 34 25·4
α Lyræ, ... *Vega*	0·1	18 34 33	N. 38 43·2
σ Sagittarii, ...	2·1	18 50 54	S. 26 23·3
α Aquilæ, ... *Altair*	0·9	19 47 21	N. 8 40·9
α Pavonis, ...	2·1	20 20 07	S. 56 58·0
α Cygni, ... *Deneb*	1·3	20 39 03	N. 45 01·8
α Gruis, ...	2·2	22 03 50	S. 47 18·2
β Gruis, ...	2·2	22 38 30	S. 47 15·2
α Piscis Australis, . . *Fomalhaut*	1·3	22 53 47	S. 29 59·7

SEPTEMBER, 1929.

Date.		Day of Year.	Sun's Semi-diameter.	THE MOON'S							Age at 0h.
				Semi-diameter.	Horizontal Parallax.	Meridian Passage.					
						Upper.		Diff.	Lower.		Diff.
			′	′	′	h.	m.	m.	h.	m.	m.	d.
Sun.	1	244	15·9	16·4	60·2	10	17	57	22	46	55	26·9
Mon.	2	245	15·9	16·4	60·1	11	14	53	23	41	51	27·9
Tues.	3	246	15·9	16·3	59·7	12	07	49	*	*		28·9
Wed.	4	247	15·9	16·1	59·2	12	56	47	00	32	48	0·5
Thur.	5	248	15·9	15·9	58·5	13	43	46	01	20	46	1·5
Fri.	6	249	15·9	15·7	57·7	14	29	45	02	06	46	2·5
Sat.	7	250	15·9	15·5	56·9	15	14	46	02	52	45	3·5
Sun.	8	251	15·9	15·3	56·1	16	00	48	03	37	47	4·5
Mon.	9	252	15·9	15·1	55·4	16	48	49	04	24	48	5·5
Tues.	10	253	15·9	15·0	54·9	17	37	50	05	12	50	6·5
Wed.	11	254	15·9	14·8	54·5	18	27	51	06	02	51	7·5
Thur.	12	255	15·9	14·8	54·3	19	18	51	06	53	51	8·5
Fri.	13	256	15·9	14·8	54·2	20	09	50	07	44	50	9·5
Sat.	14	257	15·9	14·8	54·3	20	59	48	08	34	49	10·5
Sun.	15	258	15·9	14·9	54·6	21	47	46	09	23	47	11·5
Mon.	16	259	15·9	15·0	55·0	22	33	45	10	10	45	12·5
Tues.	17	260	15·9	15·1	55·4	23	18	44	10	55	45	13·5
Wed.	18	261	15·9	15·2	55·9	*	*		11	40	43	14·5
Thur.	19	262	16·0	15·4	56·5	00	02	43	12	23	45	15·5
Fri.	20	263	16·0	15·5	57·0	00	45	45	13	08	46	16·5
Sat.	21	264	16·0	15·7	57·5	01	30	48	13	54	49	17·5
Sun.	22	265	16·0	15·8	58·0	02	18	50	14	43	52	18·5
Mon.	23	266	16·0	15·9	58·4	03	08	55	15	35	57	19·5
Tues.	24	267	16·0	16·0	58·7	04	03	59	16	32	60	20·5
Wed.	25	268	16·0	16·1	59·0	05	02	62	17	32	63	21·5
Thur.	26	269	16·0	16·1	59·2	06	04	62	18	35	61	22·5
Fri.	27	270	16·0	16·2	59·4	07	06	60	19	36	59	23·5
Sat.	28	271	16·0	16·2	59·4	08	06	58	20	35	56	24·5
Sun.	29	272	16·0	16·2	59·4	09	04	53	21	31	51	25·5
Mon.	30	273	16·0	16·1	59·2	09	57	50	22	22	48	26·5
Tues.	31	274	16·0	16·0	58·9	10	47		23	10		27·5

SEPTEMBER, 1929.

THE SUN.

G.M.T.	Friday 20									Thursday 26								
	R.			Dec.			*E.*			*R.*			Dec.			*E.*		
h.	h.	m.	s.		°	′	h.	m.	s.	h.	m.	s.		°	′	h.	m.	s.
00	23	53	35·3	N.	1	22·5	12	06	17·1	00	17	14·6	S.	0	57·6	12	08	23·0
02	23	53	55·0		1	20·6	12	06	18·8	00	17	34·3		0	59·6	12	08	24·8
04	23	54	14·7		1	18·7	12	06	20·6	00	17	54·0		1	01·5	12	08	26·5
06	23	54	34·4		1	16·7	12	06	22·4	00	18	13·7		1	03·5	12	08	28·2
08	23	54	54·1		1	14·8	12	06	24·2	00	18	33·5		1	05·4	12	08	29·9
10	23	55	13·8		1	12·8	12	06	25·9	00	18	53·2		1	07·4	12	08	31·6
12	23	55	33·6		1	10·9	12	06	27·7	00	19	12·9		1	09·3	12	08	33·3
14	23	55	53·3		1	09·0	12	06	29·5	00	19	32·6		1	11·3	12	08	35·0
16	23	56	13·0		1	07·0	12	06	31·2	00	19	52·3		1	13·2	12	08	36·7
18	23	56	32·7		1	05·1	12	06	33·0	00	20	12·0		1	15·2	12	08	38·4
20	23	56	52·4		1	03·1	12	06	34·8	00	20	31·7		1	17·1	12	08	40·1
22	23	57	12·1		1	01·2	12	06	36·6	00	20	51·4		1	19·1	12	08	41·8
	Monday 23									Friday 27								
00	00	05	24·9	N.	0	12·5	12	07	20·6	00	21	11·2	S.	1	21·0	12	08	43·5
02	00	05	44·7		0	10·6	12	07	22·4	00	21	30·9		1	23·0	12	08	45·2
04	00	06	04·4		0	08·6	12	07	24·1	00	21	50·6		1	24·9	12	08	46·9
06	00	06	24·1		0	06·7	12	07	25·9	00	22	10·3		1	26·9	12	08	48·6
08	00	06	43·8		0	04·8	12	07	27·6	00	22	30·0		1	28·8	12	08	50·3
10	00	07	03·5		0	02·8	12	07	29·4	00	22	49·7		1	30·8	12	08	52·0
12	00	07	23·2	N.	0	00·9	12	07	31·1	00	23	09·4		1	32·7	12	08	53·7
14	00	07	42·9	S.	0	01·1	12	07	32·8	00	23	29·1		1	34·7	12	08	55·3
16	00	08	02·6		0	03·0	12	07	34·6	00	23	48·9		1	36·6	12	08	57·0
18	00	08	22·4		0	05·0	12	07	36·3	00	24	08·6		1	38·6	12	08	58·7
20	00	08	42·1		0	06·9	12	07	38·1	00	24	28·3		1	40·5	12	09	00·4
22	00	09	01·8		0	08·9	12	07	39·8	00	24	48·0	S.	1	42·5	12	09	02·1
	Tuesday 24									Saturday 28								
00	00	09	21·5	S.	0	10·8	12	07	41·6	00	25	07·7	S.	1	44·4	12	09	03·8
02	00	09	41·2		0	12·8	12	07	43·3	00	25	27·4		1	46·4	12	09	05·4
04	00	10	00·9		0	14·7	12	07	45·1	00	25	47·1		1	48·3	12	09	07·1
06	00	10	20·6		0	16·7	12	07	46·8	00	26	06·8		1	50·3	12	09	08·8
08	00	10	40·3		0	18·6	12	07	48·5	00	26	26·6		1	52·2	12	09	10·4
10	00	11	00·1		0	20·6	12	07	50·3	00	26	46·3		1	54·2	12	09	12·1
12	00	11	19·8		0	22·5	12	07	52·0	00	27	06·0		1	56·1	12	09	13·8
14	00	11	39·5		0	24·5	12	07	53·7	00	27	25·7		1	58·1	12	09	15·5
16	00	11	59·2		0	26·4	12	07	55·5	00	27	45·4		2	00·0	12	09	17·1
18	00	12	18·9		0	28·4	12	07	57·2	00	28	05·1		2	02·0	12	09	18·8
20	00	12	38·6		0	30·3	12	07	58·9	00	28	24·8		2	03·9	12	09	20·4
22	00	12	58·3	S.	0	32·3	12	08	00·7	00	28	44·5	S.	2	05·8	12	09	22·1

R. is the Right Ascension of the Mean Sun $\pm$ 12 hours. *E.* is 12 hours minus the Equation of Time.

DECEMBER, 1929.

Star's Name.	Mag.	Right Ascension.	Declination.
		h. m. s.	° ′
α Andromedæ, ... *Alpheratz*	2·2	00 04 45	N. 28 42·3
α Phœnicis, ...	2·4	00 22 50	S. 42 41·4
α Cassiopeiæ, ... *Schedar*	2·1-2·6	00 36 30	N. 56 09·4
β Ceti, ...	2·2	00 40 04	S. 18 22·4
β Andromedæ, ...	2·4	01 05 48	N. 35 15·1
α Ursæ Minoris, ... *Polaris*	2·1	01 37 00	N. 88 56·0
α Eridani, ... *Achernar*	0·6	01 35 08	S. 57 35·8
γ Andromedæ, ...	2·2	01 59 35	N. 41 59·9
α Arietis, ... *Hamal*	2·2	02 03 13	N. 23 08·0
α Persei, ... *Mirfak*	1·9	03 19 19	N. 49 37·0
α Tauri, ... *Aldebaran*	1·1	04 31 54	N. 16 22·3
β Orionis, ... *Rigel*	0·3	05 11 11	S. 8 16·8
α Aurigæ, ... *Capella*	0·2	05 11 32	N. 45 55·9
γ Orionis, ... *Bellatrix*	1·7	05 21 23	N. 6 17·4
β Tauri, ... *Nath*	1·8	05 21 52	N. 28 33·1
ε Orionis, ...	1·8	05 32 40	S. 1 14·6
ζ Orionis, ...	1·9	05 37 14	S. 1 58·6
α Orionis, ... *Betelguese*	0·5-1·1	05 51 23	N. 7 23·8
β Aurigæ, ...	2·1	05 54 24	N. 44 56·6
β Canis Majoris, ... *Mirzam*	2·0	06 19 38	S. 17 55·0
α Argus, ... *Canopus*	−0·9	06 22 26	S. 52 39·2
γ Geminorum, ... *Alhena*	1·9	06 33 41	N. 16 27·7
α Canis Majoris, ... *Sirius*	−1·6	06 42 04	S. 16 37·0
ε Canis Majoris, ...	1·6	06 55 53	S. 28 52·4
δ Canis Majoris, ...	2·0	07 05 33	S. 26 16·7
α Geminorum, ... *Castor*	1·6	07 30 09	N. 32 02·7
α Canis Minoris, ... *Procyon*	0·5	07 35 39	N. 5 24·5
β Geminorum, ... *Pollux*	1·2	07 41 02	N. 28 11·9
γ Argus, ...	1·9	08 07 23	S. 47 07·5
ε Argus, ...	1·7	08 21 06	S. 59 16·7
δ Argus, ...	2·0	08 42 47	S. 54 26·7
β Argus, ...	1·8	09 12 28	S. 69 25·3
α Hydræ, ... *Alphard*	2·2	09 24 09	S. 8 21·1
α Leonis, ... *Regulus*	1·3	10 04 39	N. 12 18·7
γ Leonis, ...	2·3	10 16 07	N. 20 11·8
β Ursæ Majoris, ...	2·4	10 57 38	N. 56 45·3
α Ursæ Majoris, ... *Dubhe*	2·0	10 59 26	N. 62 07·6
α Crucis, ...	1·1	12 22 39	S. 62 42·3
γ Crucis, ...	1·6	12 27 14	S. 56 42·9
β Crucis, ...	1·5	12 43 35	S. 59 18·0
ε Ursæ Majoris, ... *Alioth*	1·7	12 50 56	N. 56 20·2
β Ursæ Majoris, ... *Mizar*	2·2	13 21 05	N. 55 17·2
α Virginis, ... *Spica*	1·2	13 21 29	S. 10 47·7
η Ursæ Majoris, ... *Benetnasch*	1·9	13 44 46	N. 49 39·6
β Centauri, ...	0·9	13 58 49	S. 60 01·9
α Bootis, ... *Arcturus*	0·2	14 12 27	N. 19 32·7
α Centauri, ...	0·1	14 34 46	S. 60 32·6
β Ursæ Minoris, ... *Kochab*	2·2	14 50 51	N. 74 26·3
α Coronæ Borealis, . . . *Alphacca*	2·3	15 31 42	N. 26 56·9
α Trianguli Australis, ...	1·9	16 41 08	S. 68 54·1
α Ophiuchi, ...	2·1	17 31 39	N. 12 36·5
α Lyræ, ... *Vega*	0·1	18 34 32	N. 38 43·0
α Aquilæ, ... *Altair*	0·9	19 47 20	N. 8 40·8
α Pavonis, ...	2·1	20 20 05	S. 56 58·0
α Cygni, ... *Deneb*	1·3	20 39 00	N. 45 01·8
α Gruis, ...	2·2	22 03 48	S. 47 18·4
β Gruis, ...	2·2	22 38 29	S. 47 15·4
α Piscis Australis, . . *Fomalhaut*	1·3	22 53 46	S. 29 59·9

DECEMBER, 1929.

Date.		Day of Year.	Sun's Semi-diameter.	THE MOON'S								
				Semi-diameter.	Horizontal Parallax.	Meridian Passage. Upper.		Diff.	Meridian Passage. Lower.		Diff.	Age at 0^h.
			′	′	′	h.	m.	m.	h.	m.	m.	d.
Sun.	**1**	335	16·2	15·0	54·9	12	02		*	*		29·5
								51				
Mon.	**2**	336	16·3	14·9	54·6	12	53		00	27		0·8
								51			52	
Tues.	**3**	337	16·3	14·8	54·3	13	44		01	19		1·8
								52			51	
Wed.	**4**	338	16·3	14·7	54·1	14	36		02	10		2·8
								49			51	
Thur.	**5**	339	16·3	14·7	54·0	15	25		03	01		3·8
								47			48	
Fri.	**6**	340	16·3	14·7	54·1	16	12		03	49		4·8
								45			46	
Sat.	**7**	341	16·3	14·8	54·2	16	57		04	35		5·8
								43			44	
Sun.	**8**	342	16·3	14·9	54·6	17	40		05	19		6·8
								42			43	
Mon.	**9**	343	16·3	15·0	55·1	18	22		06	02		7·8
								43			42	
Tues.	**10**	344	16·3	15·2	55·8	19	05		06	44		8·8
								43			42	
Wed.	**11**	345	16·3	15·4	56·6	19	48		07	26		9·8
								47			45	
Thur.	**12**	346	16·3	15·7	57·5	20	35		08	11		10·8
								50			48	
Fri.	**13**	347	16·3	15·9	58·5	21	25		08	59		11·8
								56			53	
Sat.	**14**	348	16·3	16·2	59·4	22	21		09	52		12·8
								62			59	
Sun.	**15**	349	16·3	16·4	60·2	23	23		10	51		13·8
								66			65	
Mon.	**16**	350	16·3	16·6	60·8	*	*		11	56		14·8
											67	
Tues.	**17**	351	16·3	16·7	61·1	00	29		13	03		15·8
								67			66	
Wed.	**18**	352	16·3	16·7	61·1	01	36		14	09		16·8
								65			62	
Thur.	**19**	353	16·3	16·6	60·8	02	41		15	11		17·8
								60			57	
Fri.	**20**	354	16·3	16·4	60·3	03	41		16	08		18·8
								54			52	
Sat.	**21**	355	16·3	16·2	59·6	04	35		17	00		19·8
								49			48	
Sun.	**22**	356	16·3	16·0	58·7	05	24		17	48		20·8
								46			45	
Mon.	**23**	357	16·3	15·8	57·9	06	10		18	33		21·8
								45			44	
Tues.	**24**	358	16·3	15·6	57·1	06	55		19	17		22·8
								44			44	
Wed.	**25**	359	16·3	15·4	56·4	07	39		20	01		23·8
								44			45	
Thur.	**26**	360	16·3	15·2	55·8	08	23		20	46		24·8
								47			47	
Fri.	**27**	361	16·3	15·1	55·3	09	10		21	33		25·8
								48			49	
Sat.	**28**	362	16·3	14·9	54·8	09	58		22	22		26·8
								50			51	
Sun.	**29**	363	16·3	14·8	54·5	10	48		23	13		27·8
								51			52	
Mon.	**30**	364	16·3	14·8	54·2	11	39		*	*		28·8
								51				
Tues.	**31**	365	16·3	14·7	54·1	12	30		00	05		0·0
								50			51	
Wed.	**32**	366	16·3	14·7	54·0	13	20		00	56		1·0

DECEMBER, 1929.

THE SUN.

G.M.T.	Monday 23									Friday 27								
	R.			Dec.			*E.*			*R.*			Dec.			*E.*		
h.	h.	m.	s.	°	′		h.	m.	s.	h.	m.	s.	°	′		h.	m.	s.
00	06	04	11·5	S. 23	26·9		12	01	12·7	06	19	57·8	S. 23	21·9		11	59	13·1
02	06	04	31·3	23	26·9		12	01	10·2	06	20	17·5	23	21·7		11	59	10·6
04	06	04	51·0	23	26·8		12	01	07·7	06	20	37·2	23	21·5		11	59	08·2
06	06	05	10·7	23	26·8		12	01	05·2	06	20	56·9	23	21·3		11	59	05·7
08	06	05	30·4	23	26·8		12	01	02·7	06	21	16·6	23	21·1		11	59	03·2
10	06	05	50·1	23	26·7		12	01	00·2	06	21	36·4	23	20·9		11	59	00·7
12	06	06	09·8	23	26·7		12	00	57·7	06	21	56·1	23	20·7		11	58	58·3
14	06	06	29·5	23	26·6		12	00	55·2	06	22	15·8	23	20·5		11	58	55·8
16	06	06	49·3	23	26·6		12	00	52·7	06	22	35·5	23	20·3		11	58	53·3
18	06	07	09·0	23	26·5		12	00	50·2	06	22	55·2	23	20·1		11	58	50·8
20	06	07	28·7	23	26·5		12	00	47·7	06	23	14·9	23	19·9		11	58	48·4
22	06	07	48·4	23	26·4		12	00	45·2	06	23	34·6	23	19·6		11	58	45·9
	Tuesday 24									Saturday 28								
00	06	08	08·1	S. 23	26·3		12	00	42·7	06	23	54·3	S. 23	19·4		11	58	43·4
02	06	08	27·8	23	26·3		12	00	40·3	06	24	14·1	23	19·2		11	58	41·0
04	06	08	47·5	23	26·2		12	00	37·8	06	24	33·8	23	19·0		11	58	38·5
06	06	09	07·2	23	26·1		12	00	35·3	06	24	53·5	23	18·7		11	58	36·0
08	06	09	27·0	23	26·0		12	00	32·8	06	25	13·2	23	18·5		11	58	33·6
10	06	09	46·7	23	26·0		12	00	30·3	06	25	32·9	23	18·3		11	58	31·1
12	06	10	06·4	23	25·9		12	00	27·8	06	25	52·6	23	18·0		11	58	28·6
14	06	10	26·1	23	25·8		12	00	25·3	06	26	12·3	23	17·8		11	58	26·2
16	06	10	45·8	23	25·7		12	00	22·8	06	26	32·1	23	17·5		11	58	23·7
18	06	11	05·5	23	25·6		12	00	20·3	06	26	51·8	23	17·3		11	58	21·2
20	06	11	25·2	23	25·5		12	00	17·8	06	27	11·5	23	17·0		11	58	18·8
22	06	11	45·0	23	25·4		12	00	15·3	06	27	31·2	23	16·8		11	58	16·3
	Wednesday 25									Sunday 29								
00	06	12	04·7	S. 23	25·3		12	00	12·8	06	27	50·9	S. 23	16·5		11	58	13·9
02	06	12	24·4	23	25·2		12	00	10·3	06	28	10·6	23	16·3		11	58	11·4
04	06	12	44·1	23	25·1		12	00	07·8	06	28	30·3	23	16·0		11	58	09·0
06	06	13	03·8	23	25·0		12	00	05·4	06	28	50·0	23	15·7		11	58	06·5
08	06	13	23·5	23	24·9		12	00	02·9	06	29	09·8	23	15·5		11	58	04·1
10	06	13	43·2	23	24·7		12	00	00·4	06	29	29·5	23	15·2		11	58	01·6
12	06	14	03·0	23	24·6		11	59	57·9	06	29	49·2	23	14·9		11	57	59·2
14	06	14	22·7	23	24·5		11	59	55·4	06	30	08·9	23	14·6		11	57	56·7
16	06	14	42·4	23	24·4		11	59	52·9	06	30	28·6	23	14·3		11	57	54·3
18	06	15	02·1	23	24·2		11	59	50·4	06	30	48·3	23	14·0		11	57	51·9
20	06	15	21·8	23	24·1		11	59	47·9	06	31	08·0	23	13·7		11	57	49·4
22	06	15	41·5	23	24·0		11	59	45·4	06	31	27·8	23	13·5		11	57	47·0
	Thursday 26									Monday 30								
00	06	16	01·2	S. 23	23·8		11	59	42·9	06	31	47·5	S. 23	13·2		11	57	44·5
02	06	16	20·9	23	23·7		11	59	40·4	06	32	07·2	23	12·9		11	57	42·1
04	06	16	40·7	23	23·5		11	59	37·9	06	32	26·9	23	12·5		11	57	39·7
06	06	17	00·4	23	23·4		11	59	35·5	06	32	46·6	23	12·2		11	57	37·2
08	06	17	20·1	23	23·2		11	59	33·0	06	33	06·3	23	11·9		11	57	34·8
10	06	17	39·8	23	23·1		11	59	30·5	06	33	26·0	23	11·6		11	57	32·4
12	06	17	59·5	23	22·9		11	59	28·0	06	33	45·8	23	11·3		11	57	29·9
14	06	18	19·2	23	22·7		11	59	25·5	06	34	05·5	23	11·0		11	57	27·5
16	06	18	38·9	23	22·6		11	59	23·0	06	34	25·2	23	10·6		11	57	25·1
18	06	18	58·6	23	22·4		11	59	20·6	06	34	44·9	23	10·3		11	57	22·7
20	06	19	18·4	23	22·2		11	59	18·1	06	35	04·6	23	10·0		11	57	20·2
22	06	19	38·1	S. 23	22·0		11	59	15·6	06	35	24·3	S. 23	09·7		11	57	17·8

R. is the Right Ascension of the Mean Sun ± 12 hours. *E.* is 12 hours minus the Equation of Time.

POLE STAR TABLES, 1929.

USED IN DETERMINING LATITUDE BY OBSERVATIONS OF THE POLE STAR OUT OF THE MERIDIAN.

TABLE I.—Containing the *First* Correction.

Argument.—Local Sidereal Time of Observation.

	00h	01h	02h	03h	04h	05h	06h	07h	08h	09h	10h	11h
m	° ′	° ′	° ′	′	′	′	′	′	′	′	′	′
00	−0 58·5	−1 03·2	−1 03·6	−59·7	−51·8	−40·3	−26·0	−10·0	+ 6·7	+22·9	+37·6	+49·7
02	0 58·7	1 03·3	1 03·6	59·5	51·4	39·8	25·5	9·5	7·2	23·5	38·1	50·1
04	0 58·9	1 03·4	1 03·5	59·3	51·1	39·4	25·0	8·9	7·8	24·0	38·5	50·4
06	0 59·1	1 03·4	1 03·4	59·1	50·8	39·0	24·5	8·4	8·4	24·5	39·0	50·8
08	0 59·3	1 03·5	1 03·4	58·9	50·4	38·5	24·0	7·8	8·9	25·0	39·4	51·1
10	−0 59·5	−1 03·6	−1 03·3	−58·7	−50·1	−38·1	−23·5	− 7·2	+ 9·5	+25·5	+39·8	+51·4
12	0 59·7	1 03·6	1 03·2	58·5	49·7	37·6	22·9	6·7	10·0	26·0	40·3	51·8
14	0 59·9	1 03·7	1 03·1	58·2	49·4	37·2	22·4	6·1	10·6	26·5	40·7	52·1
16	1 00·1	1 03·8	1 03·0	58·0	49·0	36·7	21·9	5·6	11·1	27·0	41·1	52·4
18	1 00·3	1 03·8	1 02·9	57·8	48·7	36·2	21·4	5·0	11·7	27·6	41·6	52·7
20	−1 00·5	−1 03·8	−1 02·8	−57·5	−48·3	−35·8	−20·8	− 4·5	+12·2	+28·1	+42·0	+53·1
22	1 00·7	1 03·9	1 02·7	57·3	47·9	35·3	20·3	3·9	12·8	28·6	42·4	53·4
24	1 00·9	1 03·9	1 02·6	57·0	47·6	34·9	19·8	3·3	13·3	29·1	42·8	53·7
26	1 01·0	1 03·9	1 02·5	56·8	47·2	34·4	19·2	2·8	13·8	29·5	43·2	54·0
28	1 01·2	1 04·0	1 02·4	56·5	46·8	33·9	18·7	2·2	14·4	30·0	43·6	54·3
30	−1 01·4	−1 04·0	−1 02·2	−56·2	−46·4	−33·4	−18·2	− 1·7	+14·9	+30·5	+44·1	+54·6
32	1 01·5	1 04·0	1 02·1	56·0	46·0	33·0	17·6	1·1	15·5	31·0	44·5	54·9
34	1 01·7	1 04·0	1 02·0	55·7	45·7	32·5	17·1	− 0·6	16·0	31·5	44·9	55·1
36	1 01·8	1 04·0	1 01·8	55·4	45·3	32·0	16·6	0·0	16·6	32·0	45·3	55·4
38	1 02·0	1 04·0	1 01·7	55·1	44·9	31·5	16·0	+ 0·6	17·1	32·5	45·7	55·7
40	−1 02·1	−1 04·0	−1 01·5	−54·9	−44·5	−31·0	−15·5	+ 1·1	+17·6	+33·0	+46·0	+56·0
42	1 02·2	1 04·0	1 01·4	54·6	44·1	30·5	14·9	1·7	18·2	33·4	46·4	56·2
44	1 02·4	1 04·0	1 01·2	54·3	43·6	30·0	14·4	2·2	18·7	33·9	46·8	56·5
46	1 02·5	1 03·9	1 01·0	54·0	43·2	29·5	13·8	2·8	19·2	34·4	47·2	56·8
48	1 02·6	1 03·9	1 00·9	53·7	42·8	29·1	13·3	3·3	19·8	34·9	47·6	57·0
50	−1 02·7	−1 03·9	−1 00·7	−53·4	−42·4	−28·6	−12·8	+ 3·9	+20·3	+35·3	+47·9	+57·3
52	1 02·8	1 03·8	1 00·5	53·1	42·0	28·1	12·2	4·5	20·8	35·8	48·3	57·5
54	1 02·9	1 03·8	1 00·3	52·7	41·6	27·6	11·7	5·0	21·4	36·2	48·7	57·8
56	1 03·0	1 03·8	1 00·1	52·4	41·1	27·0	11·1	5·6	21·9	36·7	49·0	58·0
58	1 03·1	1 03·7	0 59·9	52·1	40·7	26·5	10·6	6·1	22·4	37·2	49·4	58·2
60	−1 03·2	−1 03·6	−0 59·7	−51·8	−40·3	−26·0	−10·0	+ 6·7	+22·9	+37·6	+49·7	+58·5

TABLE I.—*Continued.*—Containing the *First* Correction.

Argument.—Local Sidereal Time of Observation.

	12h	13h	14h	15h	16h	17h	18h	19h	20h	21h	22h	23h
m	° ′	° ′	° ′	′	′	′	′	′	′	′	′	′
00	+0 58·5	+1 03·2	+1 03·6	+59·7	+51·8	+40·3	+26·0	+10·0	− 6·7	−22·9	−37·6	−49·7
02	0 58·7	1 03·3	1 03·6	59·5	51·4	39·8	25·5	9·5	7·2	23·5	38·1	50·1
04	0 58·9	1 03·4	1 03·5	59·3	51·1	39·4	25·0	8·9	7·8	24·0	38·5	50·4
06	0 59·1	1 03·4	1 03·4	59·1	50·8	39·0	24·5	8·4	8·4	24·5	39·0	50·8
08	0 59·3	1 03·5	1 03·4	58·9	50·4	38·5	24·0	7·8	8·9	25·0	39·4	51·1
10	+0 59·5	+1 03·6	+1 03·3	+58·7	+50·1	+38·1	+23·5	+ 7·2	− 9·5	−25·5	−39·8	−51·4
12	0 59·7	1 03·6	1 03·2	58·5	49·7	37·6	22·9	6·7	10·0	26·0	40·3	51·8
14	0 59·9	1 03·7	1 03·1	58·2	49·4	37·2	22·4	6·1	10·6	26·5	40·7	52·1
16	1 00·1	1 03·8	1 03·0	58·0	49·0	36·7	21·9	5·6	11·1	27·0	41·1	52·4
18	1 00·3	1 03·8	1 02·9	57·8	48·7	36·2	21·4	5·0	11·7	27·6	41·6	52·7
20	+1 00·5	+1 03·8	+1 02·8	+57·5	+48·3	+35·8	+20·8	+ 4·5	−12·2	−28·1	−42·0	−53·1
22	1 00·7	1 03·9	1 02·7	57·3	47·9	35·3	20·3	3·9	12·8	28·6	42·4	53·4
24	1 00·9	1 03·9	1 02·6	57·0	47·6	34·9	19·8	3·3	13·3	29·1	42·8	53·7
26	1 01·0	1 03·9	1 02·5	56·8	47·2	34·4	19·2	2·8	13·8	29·5	43·2	54·0
28	1 01·2	1 04·0	1 02·4	56·5	46·8	33·9	18·7	2·2	14·4	30·0	43·6	54·3
30	+1 01·4	+1 04·0	+1 02·2	+56·2	+46·4	+33·4	+18·2	+ 1·7	−14·9	−30·5	−44·1	−54·6
32	1 01·5	1 04·0	1 02·1	56·0	46·0	33·0	17·6	1·1	15·5	31·0	44·5	54·9
34	1 01·7	1 04·0	1 02·0	55·7	45·7	32·5	17·1	+ 0·6	16·0	31·5	44·9	55·1
36	1 01·8	1 04·0	1 01·8	55·4	45·3	32·0	16·6	0·0	16·6	32·0	45·3	55·4
38	1 02·0	1 04·0	1 01·7	55·1	44·9	31·5	16·0	− 0·6	17·1	32·5	45·7	55·7
40	+1 02·1	+1 04·0	+1 01·5	+54·9	+44·5	+31·0	+15·5	− 1·1	−17·6	−33·0	−46·0	−56·0
42	1 02·2	1 04·0	1 01·4	54·6	44·1	30·5	14·9	1·7	18·2	33·4	46·4	56·2
44	1 02·4	1 04·0	1 01·2	54·3	43·6	30·0	14·4	2·2	18·7	33·9	46·8	56·5
46	1 02·5	1 03·9	1 01·0	54·0	43·2	29·5	13·8	2·8	19·2	34·4	47·2	56·8
48	1 02·6	1 03·9	1 00·9	53·7	42·8	29·1	13·3	3·3	19·8	34·9	47·6	57·0
50	+1 02·7	+1 03·9	+1 00·7	+53·4	+42·4	+28·6	+12·8	− 3·9	−20·3	−35·3	−47·9	−57·3
52	1 02·8	1 03·8	1 00·5	53·1	42·0	28·1	12·2	4·5	20·8	35·8	48·3	57·5
54	1 02·9	1 03·8	1 00·3	52·7	41·6	27·6	11·7	5·0	21·4	36·2	48·7	57·8
56	1 03·0	1 03·8	1 00·1	52·4	41·1	27·0	11·1	5·6	21·9	36·7	49·0	58·0
58	1 03·1	1 03·7	0 59·9	52·1	40·7	26·5	10·6	6·1	22·4	37·2	49·4	58·2
60	+1 03·2	+1 03·6	+0 59·7	+51·8	+40·3	+26·0	+10·0	− 6·7	−22·9	−37·6	−49·7	−58·5

POLE STAR TABLES, 1929.

TABLE II.—Containing the *Second* Correction (*always to be added*).

Arguments.—Local Sidereal Time and Altitude.

Local Sidereal Time.	ALTITUDE.													Local Sidereal Time.
	10°	15°	20°	25°	30°	35°	40°	45°	50°	55°	0°	65°	70°	
h m	′	′	′	′	′	′	′	′	′	′	′	′	′	h m
00 00	0·0	0·0	0·0	0·0	0·1	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·3	12 00
20	0·0	0·0	0·0	0·0	0·0	0·0	0·1	0·1	0·1	0·1	0·1	0·1	0·2	20
40	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·1	0·1	0·1	0·1	40
01 00	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	13 00
20	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	20
40	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	40
02 00	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	14 00
20	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·1	0·1	20
40	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·1	0·1	0·1	0·1	0·1	40
03 00	0·0	0·0	0·0	0·0	0·0	0·1	0·1	0·1	0·1	0·1	0·1	0·2	0·2	15 00
20	0·0	0·0	0·0	0·1	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·3	20
40	0·0	0·0	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·3	0·3	0·4	40
04 00	0·0	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·3	0·4	0·4	0·6	16 00
20	0·0	0·1	0·1	0·1	0·1	0·2	0·2	0·3	0·3	0·4	0·4	0·6	0·7	20
40	0·1	0·1	0·1	0·1	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·7	0·9	40
05 00	0·1	0·1	0·1	0·2	0·2	0·3	0·3	0·4	0·4	0·5	0·6	0·8	1·0	17 00
20	0·1	0·1	0·2	0·2	0·2	0·3	0·3	0·4	0·5	0·6	0·7	0·9	1·1	20
40	0·1	0·1	0·2	0·2	0·3	0·3	0·4	0·5	0·5	0·6	0·8	1·0	1·2	40
06 00	0·1	0·1	0·2	0·2	0·3	0·3	0/4	0·5	0·6	0·7	0·9	1·1	1·4	18 00
20	0·1	0·1	0·2	0·2	0·3	0·4	0·4	0·5	0·6	0·8	0·9	1·1	1·5	20
40	0·1	0·2	0·2	0·3	0·3	0·4	0·5	0·6	0·7	0·8	1·0	1·2	1·5	40
07 00	0·1	0·2	0·2	0·3	0·3	0·4	0·5	0·6	0·7	0·8	1·0	1·3	1·6	19 00
20	0·1	0·2	0·2	0·3	0·3	0·4	0·5	0·6	0·7	0·8	1·0	1·3	1·6	20
40	0·1	0·2	0·2	0·3	0·3	0·4	0·5	0·6	0·7	0·8	1·0	1·3	1·6	40
08 00	0·1	0·2	0·2	0·3	0·3	0·4	0·5	0·6	0·7	0·8	1·0	1·3	1·6	20 00
20	0·1	0·2	0·2	0·3	0·3	0·4	0·5	0·6	0·7	0·8	1·0	1·2	1·6	20
40	0·1	0·1	0·2	0·3	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·2	1·5	40
09 00	0·1	0·1	0·2	0·2	0·3	0·4	0·4	0·5	0·6	0·7	0·9	1·1	1·4	21 00
20	0·1	0·1	0·2	0·2	0·3	0·3	0·4	0·5	0·6	0·7	0·8	1·0	1·3	20
40	0·1	0·1	0·2	0·2	0·2	0·3	0·4	0·4	0·5	0·6	0·8	0·9	1·2	40
10 00	0·1	0·1	0·1	0·2	0·2	0·3	0·3	0·4	0·5	0·6	0·7	0·8	1·1	22 00
20	0·1	0·1	0·1	0·2	0·2	0·2	0·3	0·3	0·4	0·5	0·6	0·7	0·9	20
40	0·0	0·1	0·1	0·1	0·2	0·2	0·2	0·3	0·3	0·4	0·5	0·6	0·8	40
11 00	0·0	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·3	0·3	0·4	0·5	0·7	23 00
20	0·0	0·0	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·3	0·3	0·4	0·5	20
40	0·0	0·0	0·1	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·2	0·3	0·4	40
12 00	0·0	0·0	0·0	0·0	0·1	0·1	0·1	0·1	0·1	0·1	0·2	0·2	0·3	24 00

TABLE III.—Containing the *Third* Correction.

Arguments.—Local Sidereal Time and Date.

Local Sidereal Time.	Jan. 1	Feb. 1	Mar. 1	April 1	May 1	June 1	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Dec. 1	Dec. 32
h	′	′	′	′	′	′	′	′	′	′	′	′	′
00	−0·3	−0·3	−0·4	−0·6	−0·7	−0·8	−0·8	−0·6	−0·5	−0·3	−0·1	0·0	+0·1
01	−0·3	−0·3	−0·4	−0·5	−0·7	−0·8	−0·8	−0·7	−0·6	−0·4	−0·2	0·0	0·0
02	−0·3	−0·3	−0·4	−0·5	−0·6	−0·7	−0·8	−0·8	−0·7	−0·5	−0·3	−0·1	0·0
03	−0·3	−0·3	−0·3	−0·4	−0·5	−0·6	−0·7	−0·8	−0·7	−0·6	−0·4	−0·2	0·0
04	−0·3	−0·2	−0·2	−0·2	−0·4	−0·5	−0·6	−0·7	−0·7	−0·6	−0·5	−0·3	−0·1
05	−0·3	−0·1	−0·1	−0·1	−0·2	−0·3	−0·5	−0·6	−0·6	−0·6	−0·5	−0·3	−0·1
06	−0·2	0·0	+0·1	+0·1	0·0	−0·1	−0·3	−0·4	−0·5	−0·5	−0·5	−0·3	−0·2
07	−0·1	0·0	+0·2	+0·2	+0·2	+0·1	−0·1	−0·2	−0·4	−0·4	−0·4	−0·3	−0·2
08	0·0	+0·1	+0·3	+0·3	+0·3	+0·3	+0·1	0·0	−0·2	−0·3	−0·4	−0·3	−0·2
09	0·0	+0·2	+0·3	+0·5	+0·5	+0·4	+0·3	+0·2	0·0	−0·2	−0·3	−0·3	−0·2
10	+0·1	+0·3	+0·4	+0·5	+0·6	+0·6	+0·5	+0·3	+0·2	0·0	−0·2	−0·2	−0·2
11	+0·2	+0·3	+0·4	+0·6	+0·7	+0·7	+0·7	+0·5	+0·3	+0·1	0·0	−0·1	−0·1
12	+0·3	+0·3	+0·4	+0·6	+0·7	+0·8	+0·8	+0·6	+0·5	+0·3	+0·1	0·0	−0·1
13	+0·3	+0·3	+0·4	+0·5	+0·7	+0·8	+0·8	+0·7	+0·6	+0·4	+0·2	0·0	0·0
14	+0·3	+0·3	+0·4	+0·5	+0·6	+0·7	+0·8	+0·8	+0·7	+0·5	+0·3	+0·1	0·0
15	+0·3	+0·3	+0·3	+0·4	+0·5	+0·6	+0·7	+0·8	+0·7	+0·6	+0·4	+0·2	0·0
16	+0·3	+0·2	+0·2	+0·2	+0·4	+0·5	+0·6	+0·7	+0·7	+0·6	+0·5	+0·3	+0·1
17	+0·3	+0·1	+0·1	+0·1	+0·2	+0·3	+0·5	+0·6	+0·6	+0·6	+0·5	+0·3	+0·1
18	+0·2	0·0	−0·1	−0·1	0·0	+0·1	+0·3	+0·4	+0·5	+0·5	+0·5	+0·3	+0·2
19	+0·1	0·0	−0·2	−0·2	−0·2	−0·1	+0·1	+0·2	+0·4	+0·4	+0·4	+0·3	+0·2
20	0·0	−0·1	−0·3	−0·3	−0·3	−0·3	−0·1	0·0	+0·2	+0·3	+0·4	+0·3	+0·2
21	0·0	−0·2	−0·3	−0·5	−0·5	−0·4	−0·3	−0·2	0·0	+0·2	+0·3	+0·3	+0·2
22	−0·1	−0·3	−0·4	−0·5	−0·6	−0·6	−0·5	−0·3	−0·2	0·0	+0·2	+0·2	+0·2
23	−0·2	−0·3	−0·4	−0·6	−0·7	−0·7	−0·7	−0·5	−0·3	−0·1	0·0	+0·1	+0·1
24	−0·3	−0·3	−0·4	−0·6	−0·7	−0·8	−0·8	−0·6	−0·5	−0·3	−0·1	0·0	+0·1

The correction given in Table III. is now the true correction, and must be applied with the sign given above. The observed altitude must *not* be diminished by 1′ as in former years.

EXTRACTS FROM THE

ADMIRALTY TIDE TABLES

CONTAINING

PART I.

TIDAL PREDICTIONS FOR STANDARD PORTS FOR THE YEAR 1925

AND

PART II.

Tidal Constants and Tidal Differences for the Principal Ports, etc.

IN EUROPEAN WATERS AND ON THE NORTH AND WEST COAST OF AFRICA TO CAPE PALMAS

PART I.

LIST OF STANDARD PORTS

	Page		Page
BOSTON, U.S.A.	461	LEITH	452
BREST	460	LIVERPOOL	456
DOVER	450	ROSYTH	453
FLUSHING	459	ST. JOHN, N.B.	462
GREENOCK	455	SHEERNESS	451
HOLYHEAD	457	SINGAPORE	463
INVERGORDON	454	WELLINGTON	464
KINGSTOWN	458		

ENGLAND, SOUTH COAST—DOVER, 1925.

Lat. 51° 07′ N. Long. 1° 19′ E.

Month Day	Week Day.	MAY. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day.	JUNE. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day.	JULY. HIGH WATER. Time H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Month Day.
1	F.	04 21	13·9	11 15	4·6	M.	06 12	13·9	00 27	3·8	W.	06 21	14·6	00 47	3·2	1
		17 00	13·8	23 55	4·6		18 40	14·5	13 06	4·4		18 44	15·4	13 15	3·8	
2	S.	05 43	13·5	—	—	Tu.	07 20	14·7	01 49	3·3	Th.	07 30	15·2	01 59	2·8	2
		18 27	13·6	12 35	5·1		19 41	15·6	14 21	3·3		19 49	16·3	14 27	3·0	
3	**S.**	07 15	13·9	01 26	4·6	W.	08 15	15·6	02 56	2·3	F.	08 25	16·3	03 07	2·1	3
		19 41	14·4	14 10	4·5		20 34	16·6	15 22	2·3		20 49	17·1	15 34	2·1	
4	M.	08 16	14·8	02 44	3·4	Th.	09 04	16·5	03 56	1·6	S.	09 19	17·1	04 12	1·6	4
		20 32	15·7	15 18	3·2		21 19	17·7	16 18	1·5		21 44	17·9	16 37	1·2	
5	Tu.	09 04	15·9	03 44	2·5	F.	09 49	17·5	04 47	0·9	**S.**	10 10	18·0	05 11	0·6	5
		21 17	16·9	16 12	2·2		22 06	18·3	17 10	0·8		22 34	18·5	17 36	0·3	
6	W.	09 43	16·9	04 37	1·2	S.	10 29	18·3	05 36	0·0	M.	10 57	18·7	06 01	*0·1	6
		21 57	17·8	16 58	1·1		22 50	19·1	17 54	0·0		23 22	19·1	18 25	*0·3	
7	Th.	10 21	17·7	05 21	0·3	**S.**	11 10	18·9	06 22	*0·6	Tu.	11 44	19·2	06 53	*0·4	7
		22 36	18·6	17 37	0·2		23 33	19·3	18 41	*0·5		—	—	19 17	*0·6	
8	F.	10 54	18·3	06 03	*0·5	M.	11 54	19·1	07 07	*0·7	W.	00 12	19·2	07 11	*0·6	8
		23 11	19·1	18 19	*0·3		—	—	19 27	*0·7		12 32	19·4	20 08	*0·7	
9	S.	11 32	18·7	06 47	*1·0	Tu.	00 18	19·3	07 53	*0·8	Th.	00 59	19·0	08 31	*0·4	9
		23 50	19·3	19 00	*0·6		12 41	19·1	20 16	*0·6		13 19	19·3	20 55	*0·2	
10	**S.**	—	—	07 27	*1·2	W.	01 08	18·8	08 39	*0·3	F.	01 51	18·8	09 18	0·4	10
		12 14	18·8	19 40	*1·0		13 29	19·1	21 01	*0·1		14 09	19·0	21 42	0·5	
11	M.	00 35	19·0	08 06	*0·8	Th.	02 00	18·3	09 26	0·4	S.	02 43	18·0	10 01	0·9	11
		12 57	18·7	20 24	*0·6		14 21	18·3	21 48	0·6		15 01	18·3	22 29	0·9	
12	Tu.	01 22	18·6	08 49	*0·3	F.	02 53	17·5	10 13	1·2	**S.**	03 39	17·2	10 46	1·6	12
		13 41	18·5	21 06	*0·1		15 16	17·3	22 42	1·5		15 55	17·6	23 17	1·9	
13	W.	02 12	17·6	09 33	0·5	S.	03 57	16·6	11 10	2·2	M.	04 37	16·2	11 37	2·5	13
		14 32	18·0	21 55	0·8		16 21	16·7	23 44	2·2		16 56	16·6	—	—	
14	Th.	03 03	17·2	10 22	1·3	**S.**	05 06	15·9	—	—	Tu.	05 38	15·3	00 13	2·7	14
		15 28	16·9	22 48	1·8		17 31	16·2	12 14	2·8		17 57	15·6	12 33	3·3	
15	F.	04 07	16·1	11 23	2·6	M.	06 22	15·4	00 53	2·5	W.	06 48	14·8	01 15	3·3	15
		16 39	15·7	23 59	2·9		18 42	15·9	13 25	3·0		19 12	15·5	13 41	3·6	
16	S.	05 29	15·3	—	—	Tu.	07 31	15·4	02 08	2·2	Th.	07 57	15·0	02 29	2·9	16
		18 02	15·3	12 39	3·1		19 49	16·0	14 34	2·5		20 20	15·5	14 52	3·2	
17	**S.**	06 52	15·4	01 24	2·7	W.	08 31	15·8	03 13	1·8	F.	08 57	15·4	03 37	3·0	17
		19 18	15·7	14 02	2·8		20 48	16·6	15 40	2·1		21 16	16·0	15 59	2·8	
18	M.	08 04	15·7	02 43	1·7	Th.	09 24	16·4	04 12	1·5	S.	09 47	16·2	04 32	2·6	18
		20 22	16·3	15 18	1·8		21 39	16·9	16 33	1·8		22 06	16·4	16 53	2·3	
19	Tu.	09 00	16·4	03 49	1·1	F.	10 08	16·7	05 02	1·3	**S.**	10 29	16·6	05 17	2·3	19
		21 14	17·2	16 16	1·1		22 23	17·1	17 19	1·4		22 47	16·8	17 39	1·7	
20	W.	09 48	17·2	04 42	0·5	S.	10 43	17·3	05 44	1·0	M.	11 05	17·0	06 00	1·6	20
		22 01	17·8	17 05	0·5		23 00	17·4	17 58	0·9		23 21	17·0	18 16	1·2	
21	Th.	10 28	17·6	05 28	0·2	**S.**	11 18	17·6	06 19	0·8	Tu.	11 37	17·5	06 35	1·3	21
		22 40	18·1	17 43	0·4		23 35	17·5	18 34	0·7		23 54	17·2	18 53	0·8	
22	F.	11 00	18·0	06 06	0·1	M.	11 52	17·6	06 54	0·9	W.	—	—	07 08	1·1	22
		23 15	18·2	18 20	0·2		—	—	19 10	0·5		12 07	17·7	19 27	0·6	
23	S.	11 36	18·0	06 43	0·1	Tu.	00 09	17·3	07 27	0·6	Th.	00 28	17·3	07 40	1·1	23
		23 52	18·2	18 55	0·1		12 26	17·3	19 43	0·5		12 38	17·7	19 57	0·8	
24	**S.**	—	—	07 16	0·2	W.	00 44	17·1	07 58	0·8	F.	01 02	17·1	08 12	1·2	24
		12 10	17·8	19 27	0·1		12 58	17·3	20 14	0·9		13 13	17·4	20 28	1·0	
25	M.	00 26	17·6	07 46	0·4	Th.	01 11	16·9	08 26	1·2	S.	01 37	16·9	08 40	1·3	25
		12 44	17·4	20 01	0·2		13 31	16·9	20 45	1·0		13 47	17·3	21 02	1·3	

The time used is STANDARD, or mean time of the meridian of Greenwich; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

ENGLAND, EAST COAST—SHEERNESS, 1925.

Lat. 51° 27′ N. Long. 0° 45′ E.

Month Day.	Week Day.	MAY. HIGH WATER. Time. H. M.	MAY. HIGH WATER. Ht. F.	MAY. LOW WATER. Time. H. M.	MAY. LOW WATER. Ht. F.	Week Day.	JUNE. HIGH WATER. Time. H. M.	JUNE. HIGH WATER. Ht. F.	JUNE. LOW WATER. Time. H. M.	JUNE. LOW WATER. Ht. F.	Week Day.	JULY. HIGH WATER. Time. H. M.	JULY. HIGH WATER. Ht. F.	JULY. LOW WATER. Time. H. M.	JULY. LOW WATER. Ht. F.	Month Day.
1	F.	05 38	13·8	11 31	3·7	M.	07 20	14·2	00 52	2·9	W.	07 35	14·5	01 11	2·5	1
		18 05	13·4	—	—		19 48	13·9	13 15	4·0		20 03	14·4	13 32	3·4	
2	S.	06 48	13·9	00 19	3·3	Tu.	08 29	14·6	02 10	2·8	Th.	08 43	14·8	02 23	2·2	2
		19 22	13·3	12 49	3·8		20 54	14·5	14 32	3·4		21 07	14·9	14 46	2·8	
3	S.	08 06	14·0	01 50	3·3	W.	09 35	15·2	03 24	2·1	F.	09 51	15·5	03 34	2·0	3
		20 36	13·8	14 15	3·6		21 54	15·3	15 38	2·7		22 12	15·4	15 58	2·3	
4	M.	09 18	14·7	03 10	2·8	Th.	10 25	15·8	04 21	1·7	S.	10 44	15·9	04 35	1·5	4
		21 44	14·7	15 30	3·1		22 45	15·9	16 36	2·0		23 08	16·2	16 57	1·7	
5	Tu.	10 20	15·5	04 14	2·0	F.	11 12	16·2	05 12	1·2	S.	11 35	16·4	05 30	1·1	5
		22 38	15·4	16 27	2·4		23 36	16·6	17 25	1·4		—	—	17 53	1·0	
6	W.	11 05	16·1	05 09	1·4	S.	11 57	16·8	05 56	0·7	M.	00 04	17·0	06 25	0·8	6
		23 26	16·3	17 13	2·1		—	—	18 15	0·8		12 28	16·9	18 49	0·5	
7	Th.	11 47	16·7	05 50	1·0	S.	00 26	17·1	06 43	0·3	Tu.	00 59	17·5	07 14	0·3	7
		—	—	17 55	1·3		12 42	17·1	19 00	0·2		13 16	17·4	19 36	0·0	
8	F.	00 08	16·9	06 31	0·5	M.	01 13	17·6	07 28	0·1	W.	01 50	17·9	08 03	0·3	8
		12 27	17·2	18 37	0·8		13 29	17·3	19 47	0·1		14 05	17·6	20 27	0·1	
9	S.	00 48	17·4	07 09	0·2	Tu.	01 56	17·8	08 13	0·4	Th.	02 37	17·9	08 49	0·7	9
		13 05	17·4	19 19	0·4		14 14	17·7	20 33	0·0		14 53	17·5	21 15	0·2	
10	S.	01 30	17·5	07 47	0·1	W.	02 44	17·7	08 59	0·6	F.	03 25	17·6	09 37	1·0	10
		13 45	17·5	20 00	0·2		15 03	17·1	21 24	0·4		15 41	17·4	22 03	0·5	
11	M.	02 11	17·7	08 27	0·4	Th.	03 32	17·3	09 47	1·2	S.	04 14	17·3	10 19	1·6	11
		14 27	17·5	20 46	0·4		15 48	16·8	22 08	1·1		16 28	16·8	22 43	1·0	
12	Tu.	02 58	17·7	09 11	0·7	F.	04 24	16·7	10 32	1·8	S.	05 06	16·7	11 03	2·0	12
		15 09	17·1	21 30	0·5		16 42	16·3	22 57	1·2		17 22	16·3	23 33	1·3	
13	W.	03 42	17·0	09 54	1·3	S.	05 23	16·5	11 27	2·5	M.	06 02	16·1	11 55	2·8	13
		15 53	16·6	22 11	1·2		17 43	15·8	23 57	1·5		18 18	15·5	—	—	
14	Th.	04 28	16·3	10 40	1·7	S.	06 31	15·5	—	—	Tu.	07 01	15·3	00 35	2·0	14
		16 47	16·0	22 56	1·7		18 55	15·3	12 31	3·0		19 20	14·9	13 00	3·1	
15	F.	05 30	15·7	11 34	2·5	M.	07 45	15·1	01 17	1·8	W.	08 07	14·7	01 43	2·4	15
		17 54	15·0	—	—		20 08	15·0	13 44	2·9		20 26	14·9	14 10	3·2	
16	S.	06 49	14·9	00 10	2·2	Tu.	08 52	15·1	02 34	1·7	Th.	09 13	14·8	02 53	2·5	16
		19 18	14·6	12 55	3·1		21 10	15·1	14 58	2·6		21 35	14·8	15 24	3·0	
17	S.	08 12	15·1	01 47	2·4	W.	09 55	15·4	03 38	1·8	F.	10 19	15·0	03 56	2·6	17
		20 38	14·9	14 13	2·8		22 11	15·1	15 59	2·4		22 36	15·0	16 26	2·8	
18	M.	09 24	15·5	03 09	1·9	Th.	10 46	15·8	04 35	1·8	S.	11 12	15·3	04 56	2·4	18
		21 44	15·4	15 33	2·2		23 04	15·6	16 55	2·0		23 27	15·2	17 21	2·4	
19	Tu.	10 23	16·0	04 12	1·5	F.	11 32	16·0	05 22	1·5	S.	11 56	15·5	05 45	2·3	19
		22 36	15·5	16 33	1·7		23 50	15·8	17 41	1·8		—	—	18 05	2·0	
20	W.	11 10	16·2	05 08	1·1	S.	—	—	06 06	1·5	M.	00 11	15·6	06 25	2·0	20
		23 24	16·0	17 23	1·4		12 12	16·0	18 26	1·3		12 37	15·9	18 45	1·6	
21	Th.	11 53	16·5	05 54	0·9	S.	00 35	15·9	06 44	1·4	Tu.	00 56	16·1	07 03	1·8	21
		—	—	18 08	1·2		12 53	15·9	19 04	1·0		13 10	16·2	19 21	1·2	
22	F.	00 12	16·3	06 35	0·7	M.	01 14	16·0	07 18	1·3	W.	01 31	16·4	07 35	1·7	22
		12 34	16·5	18 46	0·8		13 27	15·7	19 39	0·9		13 40	16·1	19 55	1·2	
23	S.	00 53	16·5	07 08	0·6	Tu.	01 50	16·0	07 54	1·2	Th.	02 04	16·5	08 07	1·6	23
		13 10	16·5	19 23	0·6		13 57	15·8	20 14	0·7		14 11	16·3	20 30	1·1	
24	S.	01 32	16·6	07 41	0·6	W.	02 21	16·3	08 25	1·2	F.	02 35	16·6	08 39	1·6	24
		13 43	16·2	19 54	0·6		14 31	15·9	20 48	0·8		14 45	16·3	21 01	1·0	
25	M.	02 04	16·3	08 10	0·9	Th.	02 52	16·2	08 56	1·5	S.	03 11	16·4	09 06	1·9	25
		14 16	15·9	20 27	0·7		15 04	15·6	21 16	1·2		15 18	15·9	21 31	1·1	

The time used is STANDARD, or mean time of the meridian of Greenwich; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

SCOTLAND, EAST COAST—LEITH, 1925.

Lat. 55° 59′ N. Long. 3° 10′ W.

Month Day.	Week Day.	JANUARY. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day.	FEBRUARY. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day.	MARCH. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Month Day.
1	Th.	07 21	15·7	00 53	3·1	S.	08 31	14·4	01 41	4·9	S.	06 49	14·7	—	—	1
		19 36	16·2	13 04	4·9		20 53	14·7	14 02	6·1		19 09	15·0	12 10	4·2	
2	F.	08 18	15·0	01 47	4·1	M.	09 25	13·8	02 44	6·2	M.	07 38	13·7	00 41	4·7	2
		20 34	15·6	14 10	5·9		21 57	14·3	15 23	6·8		20 05	14·3	12 59	5·2	
3	S.	09 16	14·7	02 54	5·0	Tu.	10 38	13·9	04 12	6·7	Tu.	08 38	13·1	01 40	6·0	3
		21 38	15·1	15 20	6·6		23 10	14·3	16 59	6·8		21 11	13·6	14 19	6·1	
4	S.	10 21	14·7	04 07	5·6	W.	11 47	14·1	05 37	6·5	W.	09 49	12·9	03 12	6·9	4
		22 49	14·9	16 38	6·5		—	—	18 04	6·2		22 30	13·4	16 05	6·5	
5	M	11 27	14·7	05 20	5·8	Th.	00 22	14·3	06 34	6·1	Th.	11 02	13·2	04 57	7·1	5
		23 56	15·1	17 42	6·0		12 49	14·7	18 57	5·3		23 45	13·8	17 33	6·0	
6	Tu.	—	—	06 17	5·4	F.	01 17	14·8	07 31	5·3	F.	—	—	06 04	6·4	6
		12 29	15·2	18 32	5·3		13 40	15·3	19 45	4·1		12 13	13·7	18 27	5·0	
7	W.	00 52	15·4	07 04	5·1	S.	02 02	15·3	08 00	4·7	S.	00 46	14·2	06 48	5·4	7
		13 20	15·7	19 20	4·6		14 19	16·0	20 22	3·6		13 07	14·5	19 13	4·3	
8	Th.	01 41	15·9	07 45	4·9	S.	02 38	16·0	08 36	4·5	S.	01 30	14·8	07 26	4·6	8
		14 04	16·3	20 02	4·1		15 00	16·8	21 01	3·1		13 50	15·5	19 52	3·1	
9	F.	02 21	16·3	08 19	4·6	M.	03 13	16·5	09 07	3·6	M.	02 10	15·6	07 58	3·7	9
		14 45	16·7	20 46	3·4		15 32	17·1	21 35	2·5		14 27	16·3	20 25	2·0	
10	S.	03 00	16·7	08 54	4·4	Tu.	03 46	16·8	09 37	3·0	Tu.	02 44	16·2	08 31	2·7	10
		15 21	17·0	21 22	3·1		16 04	17·2	22 06	1·8		14 58	17·1	20 56	1·1	
11	S.	03 36	16·9	09 29	4·2	W.	04 23	16·8	10 06	2·5	W.	03 17	16·9	09 02	2·0	11
		15 51	17·2	21 54	2·8		16 32	17·3	22 33	1·5		15 34	17·5	21 30	0·8	
12	M.	04 10	16·9	10 01	3·9	Th.	04 55	16·9	10 31	2·1	Th.	03 52	17·3	09 32	1·5	12
		16 24	17·1	22 22	3·1		17 10	17·3	23 00	1·8		16 11	17·7	22 03	0·6	
13	Tu.	04 46	16·8	10 27	4·0	F.	05 28	16·8	11 00	2·6	F.	04 14	17·2	10 02	1·3	13
		16 59	16·9	22 48	3·2		17 44	17·0	23 29	2·0		16 45	17·8	22 36	0·9	
14	W.	05 18	16·7	10 53	4·1	S.	06 03	16·4	11 40	3·4	S.	05 01	17·2	10 37	1·4	14
		17 30	16·8	23 13	3·4		18 20	16·6	—	—		17 21	17·5	23 10	1·7	
15	Th.	05 53	16·4	11 20	4·4	S.	06 45	16·0	00 06	3·1	S.	05 38	16·7	11 16	1·9	15
		18 03	16·5	23 47	3·9		19 07	16·0	12 24	4·2		17 59	16·8	23 49	2·6	
16	F.	06 29	15·7	11 56	5·0	M.	07 35	15·0	00 51	4·1	M.	06 20	15·8	—	—	16
		18 45	16·0	—	—		20 04	15·3	13 14	4·9		18 45	15·9	12 05	2·8	
17	S.	07 15	15·3	00 32	4·2	Tu.	08 33	14·6	01 53	5·0	Tu.	07 10	14·9	00 34	3·6	17
		19 36	15·6	12 43	5·7		21 11	14·9	14 26	5·3		19 42	14·9	12 57	3·8	
18	S.	08 06	15·1	01 25	4·7	W.	09 44	14·5	03 15	5·5	W.	08 11	14·4	01 37	4·7	18
		20 35	15·4	13 47	6·2		22 33	15·2	16 02	5·4		20 54	14·3	14 12	4·5	
19	M.	09 03	15·0	02 34	5·4	Th.	11 01	14·9	04 55	5·3	Th.	09 28	14·1	03 02	5·4	19
		21 41	15·3	15 05	6·5		23 53	15·6	17 40	4·8		22 23	14·5	15 59	4·5	
20	Tu.	10 11	14·9	03 55	5·8	F.	—	—	06 14	4·8	F.	10 50	14·4	04 46	5·3	20
		22 54	15·9	16 36	6·2		12 18	15·6	18 52	3·7		23 44	15·4	17 32	4·1	
21	W.	11 21	15·7	05 20	5·3	S.	01 06	16·0	07 13	3·6	S.	—	—	06 00	4·7	21
		—	—	17 52	5·1		13 21	16·6	19 48	2·4		12 05	15·4	18 34	3·3	
22	Th.	00 07	16·2	06 27	4·3	S.	01 57	17·0	08 07	2·8	S.	00 50	15·9	06 54	3·5	22
		12 33	16·4	18 57	3·9		14 14	17·7	20 38	1·7		13 10	16·3	19 29	2·0	
23	F.	01 13	16·9	07 29	3·4	M.	02 42	17·9	08 50	1·9	M.	01 42	16·8	07 39	2·2	23
		13 35	17·2	19 59	2·6		14 57	18·4	21 19	0·6		13 56	17·4	20 08	1·0	
24	S.	02 07	17·7	08 20	2·7	Tu.	03 24	18·4	09 27	1·3	Tu.	02 24	17·5	08 18	1·4	24
		14 26	18·1	20 51	1·4		15 40	18·7	21 58	0·0		14 35	18·0	20 45	0·5	
25	S.	02 57	18·4	09 09	2·0	W.	04 07	18·5	10 04	0·9	.W	03 01	18·0	08 55	0·9	25
		15 18	18·7	21 42	0·8		16 21	18·6	22 34	0·3		15 15	18·3	21 21	0·3	

The time used is STANDARD, or mean time of the meridian of Greenwich; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

SCOTLAND, EAST COAST—ROSYTH, 1925.

Lat. 56° 01′ N. Long. 3° 27′ W.

Month Day.	Week Day.	MAY. HIGH WATER. Time. H. M.	MAY. HIGH WATER. Ht. F.	MAY. LOW WATER. Time. H. M.	MAY. LOW WATER. Ht. F.	Week Day.	JUNE. HIGH WATER. Time. H. M.	JUNE. HIGH WATER. Ht. F.	JUNE. LOW WATER. Time. H. M.	JUNE. LOW WATER. Ht. F.	Week Day.	JULY. HIGH WATER. Time. H. M.	JULY. HIGH WATER. Ht. F.	JULY. LOW WATER. Time. H. M.	JULY. LOW WATER. Ht. F.	Month Day.
1	F.	08 20	13·1	00 55	6·3	M.	09 48	13·3	03 07	6·4	W.	10 03	14·0	03 18	5·6	1
		20 52	13·2	14 01	5·3		22 24	13·7	16 02	4·4		22 39	14·2	16 11	4·1	
2	S.	09 23	12·8	02 35	6·9	Tu.	10 55	13·9	04 33	5·6	Th.	11 07	14·5	04 51	4·7	2
		22 01	13·3	15 47	5·4		23 28	14·5	17 05	3·9		23 42	15·0	17 18	3·5	
3	S.	10 29	13·2	04 18	6·4	W.	11 56	14·9	05 37	4·5	F.	—	—	05 58	3·6	3
		23 10	13·9	17 05	4·9		—	—	18 00	3·3		12 11	15·4	18 20	2·8	
4	M.	11 38	14·1	05 26	5·6	Th.	00 25	15·3	06 20	3·3	S.	00 37	15·9	07 00	2·6	4
		—	—	17 55	4·1		12 54	15·7	18 49	2·3		13 09	16·2	19 17	1·9	
5	Tu.	00 09	14·6	06 05	4·6	F.	01 12	16·1	07 00	2·2	S.	01 29	16·7	07 51	1·5	5
		12 32	15·1	18 34	3·0		13 38	16·7	19 33	1·3		14 01	17·1	20 09	1·2	
6	W.	01 02	15·4	06 35	3·3	S.	01 56	17·0	07 44	1·1	M.	02 20	17·4	08 38	0·8	6
		13 20	16·0	19 03	1·9		14 25	17·3	20 12	0·9		14 49	17·7	20 52	1·0	
7	Th.	01 43	16·4	06 59	2·3	S.	02 40	17·7	08 31	0·6	Tu.	03 07	18·0	09 24	0·4	7
		14 03	16·9	19 37	0·7		15 05	17·9	20 57	0·4		15 38	18·2	21 34	1·0	
8	F.	02 23	17·1	07 35	1·4	M.	03 25	17·9	09 20	0·2	W.	04 00	18·0	09 57	0·1	8
		14 44	17·5	20 18	0·2		15 53	18·1	21 35	0·5		16 32	18·1	22 11	1·3	
9	S.	03 01	17·6	08 21	0·9	Tu.	04 13	17·6	09 59	0·3	Th.	04 50	17·8	10 31	0·5	9
		15 24	18·0	21 06	0·0		16 41	17·7	22 14	1·2		17 22	17·4	22 49	1·8	
10	S.	03 43	17·8	09 13	0·4	W.	05 03	17·2	10 32	0·8	F.	05 42	17·2	11 14	1·2	10
		16 07	18·1	21 43	0·3		17 36	17·0	22 49	1·8		18 15	16·9	23 26	2·5	
11	M.	04 25	17·4	10 00	0·4	Th.	05 59	16·4	11 18	1·5	S.	06 33	16·6	11 46	2·0	11
		16 51	17·7	22 21	1·0		18 33	16·2	23 28	2·9		19 08	16·1	—	—	
12	Tu.	05 11	16·9	10 40	0·9	F.	06 55	15·6	—	—	S.	07 29	15·8	00 20	3·6	12
		17 43	16·8	22 56	1·9		19 34	15·4	12 01	2·4		20 05	15·3	12 35	3·1	
13	W.	06 05	16·1	11 21	1·6	S.	07 54	15·1	00 33	4·0	M.	08 24	15·1	01 25	4·4	13
		18 40	15·9	23 50	3·0		20 37	14·7	13 22	3·3		21 03	14·6	13 59	4·2	
14	Th.	06 58	15·2	—	—	S.	09 02	14·8	02 11	4·7	Tu.	09 27	14·6	02 47	4·9	14
		19 39	14·9	12 07	2·7		21 43	14·3	15 12	4·0		22 03	14·1	15 21	4·8	
15	F.	08 02	14·5	00 54	4·2	M.	10 06	14·7	03 46	4·9	W.	10 29	14·5	04 03	4·8	15
		20 49	14·1	13 43	3·8		22 45	14·4	16 32	4·0		23 07	14·3	16 46	4·8	
16	S.	09 15	14·2	02 53	5·2	Tu.	11 09	14·8	05 01	4·4	Th.	11 29	14·7	05 18	4·6	16
		21 59	14·2	15 38	4·6		23 50	14·7	17 30	3·7		—	—	17 47	4·8	
17	S.	10 26	14·7	04 27	4·9	W.	—	—	05 55	3·8	F.	00 08	14·7	06 16	4·4	17
		23 14	15·0	17 14	3·9		12 13	15·2	18 24	3·3		12 29	15·0	18 37	4·3	
18	M.	11 36	15·3	05 35	4·2	Th.	00 50	15·4	06 35	3·1	S.	01 01	15·0	06 59	3·8	18
		—	—	18 07	3·2		13 08	15·7	19 06	2·9		13 20	15·4	19 13	4·4	
19	Tu.	00 19	15·5	06 15	3·5	F.	01 37	15·8	07 13	2·9	S.	01 50	15·2	07 36	3·4	19
		12 38	16·0	18 56	2·6		13 57	16·0	19 37	2·8		14 04	15·8	19 44	4·0	
20	W.	01 17	16·0	06 39	2·7	S.	02 16	15·9	07 46	2·4	M.	02 27	15·7	08 07	2·8	20
		13 34	16·4	19 18	1·8		14 31	16·1	20 00	2·7		14 41	15·9	20 14	3·6	
21	Th.	02 02	16·3	07 10	2·2	S.	02 53	15·9	08 19	2·1	Tu.	03 01	15·9	08 38	2·1	21
		14 16	16·7	19 45	1·6		15 13	16·1	20 27	2·8		15 21	16·2	20 43	3·3	
22	F.	02 38	16·5	07 46	1·7	M.	03 30	15·8	08 53	2·0	W.	03 40	16·1	09 05	1·8	22
		14 52	16·8	20 19	1·3		15 47	16·2	20 54	2·7		16 00	16·3	21 06	3·1	
23	S.	03 16	16·4	08 26	1·5	Tu.	04 03	15·7	09 16	1·8	Th.	04 12	16·2	09 31	1·7	23
		15 31	16·6	20 47	1·5		16 22	16·0	21 20	2·6		16 35	16·1	21 39	3·3	
24	S.	03 50	16·3	09 00	1·3	W.	04 37	15·5	09 45	1·9	F.	04 50	15·7	10 04	1·7	24
		16 08	16·5	21 08	1·7		16 56	15·8	21 49	3·0		17 10	16·0	22 06	3·5	
25	M.	04 26	15·9	09 29	1·5	Th.	05 15	14·9	10 20	1·9	S.	05 24	15·5	10 39	2·0	25
		16 44	16·1	21 31	2·4		17 37	15·3	22 16	3·6		17 45	15·8	22 38	3·6	

The time used is STANDARD, or mean time of the meridian of Greenwich ; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

SCOTLAND EAST COAST—INVERGORDON, 1925.

Lat. 57° 41′ N. Long. 4° 10′ W.

Month Day.	Week Day.	JANUARY. HIGH WATER. Time. H. M.	JANUARY. HIGH WATER. Ht. F.	JANUARY. LOW WATER. Time H. M.	JANUARY. LOW WATER. Ht. F.	Week Day.	FEBRUARY. HIGH WATER. Time. H. M.	FEBRUARY. HIGH WATER. Ht. F.	FEBRUARY. LOW WATER. Time. H. M.	FEBRUARY. LOW WATER. Ht. F.	Week Day.	MARCH. HIGH WATER. Time. H. M.	MARCH. HIGH WATER. Ht. F.	MARCH. LOW WATER. Time. H. M.	MARCH. LOW WATER. Ht. F.	Month Day.
1	Th.	04 44	11·8	10 15	4·7	S.	05 57	10·8	11 06	5·1	S.	04 23	11·3	09 27	3·9	1
		16 45	12·5	23 32	3·5		18 06	11·2	—	—		16 39	11·9	22 04	4·0	
2	F.	05 47	11·2	11 17	5·1	M.	06 58	10·4	00 17	4·8	M.	05 11	10·5	10 03	4·6	2
		17 49	11·9	—	—		19 08	10·8	12 17	5·6		17 28	10·9	22 53	5·0	
3	S.	06 49	10·7	00 39	4·0	Tu.	07 55	10·5	01 39	5·1	Tu.	06 07	10·1	11 31	5·2	3
		18 54	11·4	12 22	5·4		20 13	10·8	14 06	5·8		18 24	10·3	—	—	
4	S.	07 54	10·8	01 46	4·2	W.	08 53	10·6	03 04	5·1	W.	07 05	10·0	00 34	5·6	4
		19 58	11·5	13 43	5·5		21 17	11·1	15 37	5·5		19 29	10·1	13 21	5·5	
5	M.	08 51	11·1	03 00	4·3	Th.	09 49	11·1	04 05	4·9	Th.	08 04	10·3	02 30	5·8	5
		21 03	11·6	15 01	5·1		22 17	11·5	16 38	4·7		20 42	10·2	15 08	5·2	
6	Tu.	09 45	11·5	03 52	4·2	F.	10 36	12·0	04 36	4·7	F.	09 07	10·7	03 30	5·5	6
		21 55	11·5	16 02	4·7		23 05	12·0	17 17	4·0		21 48	10·8	16 08	4·5	
7	W.	10 33	12·1	04 19	4·2	S.	11 21	12·6	04 58	4·5	S.	10 04	11·3	04 11	5·1	7
		22 48	11·9	16 48	4·2		23 51	12·5	17 56	3·5		22 41	11·5	16 50	4·0	
8	Th.	11 15	12·7	04 46	4·1	S.	—	—	05 36	4·3	S.	10 53	12·0	04 38	4·4	8
		23 34	12·4	17 31	3·7		12 05	12·9	18 24	3·0		23 28	12·0	17 29	3·2	
9	F.	11 51	12·9	05 21	4·1	M.	00 29	12·8	06 15	3·8	M.	11 35	12·7	05 13	3·8	9
		—	—	18 05	3·3		12 42	13·2	18 49	2·6		—	—	18 05	2·3	
10	S.	00 12	12·6	05 58	3·9	Tu.	01 02	13·1	06 53	3·6	Tu.	00 03	12·5	05 54	3·1	10
		12 22	13·0	18 35	3·0		13 14	13·5	19 17	2·4		12 16	13·0	18 38	1·6	
11	S.	00 46	12·8	06 35	3·9	W.	01 33	13·2	07 25	3·1	W.	00 40	12·9	06 32	2·5	11
		12 55	13·1	19 00	3·0		13 47	13·6	19 50	2·3		12 55	13·4	19 12	1·0	
12	M.	01 17	12·9	07 00	4·1	Th.	02 09	13·2	07 55	3·2	Th.	01 16	13·1	07 03	1·9	12
		13 29	12·9	19 32	3·1		14 23	13·6	20 28	2·4		13 29	13·7	19 42	0·9	
13	Tu.	01 51	12·7	07 26	4·2	F.	02 47	13·0	08 27	3·3	F.	01 53	13·1	07 35	1·8	13
		14 01	13·0	20 08	3·4		15 00	13·5	21 11	2·6		14 07	13·7	20 16	1·1	
14	W.	02 25	12·5	07 58	4·2	S.	03 23	12·6	09 05	3·5	S.	02 35	13·0	08 10	1·9	14
		14 39	13·1	20 50	3·2		15 44	12·9	21 56	3·2		14 48	13·5	20 54	1·8	
15	Th.	03 03	12·3	08 30	4·3	S.	04 01	12·0	09 33	3·8	S.	03 12	12·4	08 52	2·2	15
		15 19	12·7	21 30	3·4		16 34	12·4	22 38	3·6		15 33	13·1	21 29	2·8	
16	F.	03 40	11·8	09 03	4·5	M.	04 50	11·5	10 06	4·0	M.	03 49	11·9	09 23	2·9	16
		16 03	12·4	22 23	3·6		17 26	11·7	23 38	4·0		16 19	12·3	22 04	3·8	
17	S.	04 23	11·5	00 44	4·6	Tu.	05 44	11·2	11 21	4·7	Tu.	04 31	11·5	09 52	3·7	17
		16 54	12·2	23 27	3·9		18 30	11·4	—	—		17 14	11·6	23 05	4·7	
18	S.	05 18	11·3	10 47	5·0	W.	06 51	11·1	00 48	4·6	W.	05 07	11·5	11 25	4·3	18
		17 51	11·7	—	—		19 39	11·4	13 21	4·9		18 10	11·3	—	—	
19	M.	06 19	11·2	00 40	4·3	Th.	08 01	11·4	02 34	4·6	Th.	06 27	11·3	00 52	5·1	19
		18 57	11·7	12 03	5·2		20 57	11·8	15 18	4·6		19 26	11·0	13 39	4·3	
20	Tu.	07 28	11·3	01 54	4·4	F.	09 14	12·1	03 50	4·4	F.	07 39	11·5	02 24	5·1	20
		20 06	11·9	13 47	5·0		22 14	12·4	16 36	3·4		20 52	11·4	15 26	3·7	
21	W.	08 34	11·7	03 11	4·2	S.	10 22	13·1	04 42	3·8	S.	09 01	11·9	03 36	4·3	21
		21 12	12·3	15 29	4·5		23 13	13·5	17 28	2·4		22 09	12·1	16 29	2·9	
22	Th.	09 41	12·6	04 06	3·8	S.	11 29	13·9	05 29	2·9	S.	10 12	12·7	04 26	3·5	22
		22 20	12·9	16 46	3·4		—	—	18 08	1·7		23 09	12·8	17 16	1·9	
23	F.	10 46	13·5	05 01	3·0	M.	00 06	14·4	06 15	2·5	M.	11 16	13·3	05 19	2·4	23
		23 24	13·9	17 40	2·4		12 17	14·7	18 43	1·1		23 57	13·3	17 55	1·1	
24	S.	11 40	14·5	05 41	2·7	Tu.	00 54	14·6	06 57	1·9	Tu.	—	—	05 59	1·7	24
		—	—	18 18	1·8		13 04	15·1	19 17	0·8		12 06	13·8	18 29	0·4	
25	S.	00 20	14·8	06 30	2·5	W.	01 42	14·2	07 36	1·7	W.	00 41	13·8	06 36	1·4	25
		12 30	14·9	19 09	1·3		13 49	14·8	19 57	0·6		12 49	14·1	19 01	0·2	

The time used is STANDARD, or mean time of the meridian of Greenwich; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

SCOTLAND, WEST COAST—GREENOCK, 1925.

Lat. 55° 57′ N. Long. 4° 46′ W.

Month Day.	Week Day.	JANUARY. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day.	FEBRUARY. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day.	MARCH. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Month Day.
1	Th.	04 57	10·2	10 22	1·8	S.	05 37	9·5	11 29	2·5	S.	04 20	10·7	09 52	2·2	1
		17 04	10·7	23 13	1·4		18 03	9·7	—	—		16 34	10·9	22 26	2·6	
2	F.	05 48	10·0	11 25	2·4	M.	06 38	9·4	00 21	2·8	M.	04 53	10·0	10 37	2·8	2
		18 02	10·0	—	—		19 09	9·1	12 46	3·0		17 14	9·9	23 25	3·1	
3	S.	06 40	9·9	00 19	1·8	Tu.	07 51	8·8	01 36	3·0	Tu.	05 35	9·5	11 45	3·1	3
		19 13	9·7	12 39	2·5		20 39	8·6	14 12	3·4		18 08	8·8	—	—	
4	S.	07 51	9·3	01 30	2·1	W.	09 11	8·7	02 52	2·9	W.	06 36	8·8	00 34	3·2	4
		20 26	9·3	13 56	3·0		22 07	8·5	15 28	3·1		19 41	8·0	13 17	3·1	
5	M.	09 03	9·2	02 37	2·2	Th.	10 19	9·1	03 49	2·6	Th.	08 05	8·3	01 56	3·3	5
		21 43	9·3	15 08	2·9		23 03	9·1	16 19	2·5		21 20	7·9	14 40	3·0	
6	Tu.	10 04	9·2	03 31	2·1	F.	11 01	9·5	04 35	2·5	F.	09 35	8·6	03 16	3·1	6
		22 39	9·4	16 01	2·7		23 42	9·5	16 55	2·2		22 31	8·4	15 46	2·8	
7	W.	10 48	9·6	04 17	2·1	S.	11 40	10·2	05 12	2·1	S.	10 30	9·0	04 07	2·6	7
		23 24	9·8	16 41	2·4		—	—	17 30	1·7		23 16	8·8	16 30	2·2	
8	Th.	11 28	10·2	04 57	2·0	S.	00 13	10·0	05 48	1·7	S.	11 12	9·6	04 49	2·2	8
		23 59	10·0	17 18	1·9		12 13	10·4	18 02	1·3		23 53	9·4	17 05	1·5	
9	F.	—	—	05 35	1·7	M.	00 48	9·9	06 18	1·6	M.	11 48	9·9	05 23	1·6	9
		12 00	10·3	17 49	1·6		12 46	10·9	18 30	1·0		—	—	17 37	0·8	
10	S.	00 32	10·0	06 06	1·5	Tu.	01 22	9·9	06 51	1·3	Tu.	00 28	9·7	05 54	1·3	10
		12 34	10·5	18 20	1·4		13 19	11·1	19 01	0·6		12 22	10·5	18 03	0·4	
11	S.	01 05	10·0	06 39	1·2	W.	01 56	9·8	07 23	1·3	W.	01 00	9·9	06 23	1·1	11
		13 06	11·0	18 51	0·9		13 52	11·3	19 36	0·6		12 57	10·9	18 33	0·3	
12	M.	01 39	10·0	07 13	1·2	Th.	02 33	9·9	07 56	1·1	Th.	01 30	10·1	06 53	0·7	12
		13 38	11·0	19 25	0·8		14 28	11·5	20 08	0·5		13 31	11·2	19 07	0·3	
13	Tu.	02 15	9·7	07 47	1·2	F.	03 11	10·0	08 31	1·2	F.	02 09	10·2	07 28	0·5	13
		14 07	11·1	19 57	0·7		15 06	11·4	20 45	0·9		14 10	11·1	19 44	0·3	
14	W.	02 52	9·6	08 18	1·1	S.	03 47	9·8	09 06	1·4	S.	02 49	10·2	08 06	0·6	14
		14 43	11·0	20 33	0·6		15 47	11·3	21 25	1·3		14 49	11·1	20 23	0·6	
15	Th.	03 31	9·1	08 52	1·5	S.	04 24	10·0	09 50	1·6	S.	03 27	10·3	08 44	0·7	15
		15 19	10·6	21 09	0·9		16 28	11·1	22 10	1·6		15 24	11·0	20 59	1·1	
16	F.	04 10	9·0	09 35	1·7	M.	05 05	9·9	10 44	2·0	M.	04 01	10·1	09 28	1·2	16
		16 02	10·6	21 53	1·3		17 11	10·9	23 09	2·2		16 02	10·8	21 46	1·6	
17	S.	04 50	8·9	10 21	1·7	Tu.	05 54	9·7	11 52	2·2	Tu.	04 39	9·8	10 18	1·6	17
		16 51	10·3	22 45	1·8		18 09	10·2	—	—		16 49	10·1	22 44	1·9	
18	S.	05 41	9·3	11 23	1·6	W.	07 00	9·2	00 21	2·7	W.	05 25	9·6	11 33	1·7	18
		17 44	10·0	23 48	2·2		19 31	9·2	13 18	2·4		17 52	9·3	—	—	
19	M.	06 33	9·6	—	—	Th.	08 27	9·0	01 47	2·9	Th.	06 27	9·1	00 05	2·4	19
		18 50	10·1	12 29	2·2		21 14	9·2	14 41	1·9		19 32	8·6	13 10	1·8	
20	Tu.	07 49	9·3	01 03	2·5	F.	09 58	9·5	03 10	2·4	F.	08 12	8·9	01 39	2·8	20
		20 02	9·5	13 47	2·3		22 28	9·3	15 48	1·0		21 03	9·0	14 29	1·6	
21	W.	09 04	9·3	02 18	2·5	S.	11 04	10·1	04 10	1·8	S.	09 45	9·6	03 01	2·3	21
		21 28	9·7	14 58	1·9		23 29	9·8	16 39	0·5		22 19	9·2	15 38	1·0	
22	Th.	10 15	9·8	03 25	1·9	S.	11 57	10·7	05 00	1·2	S.	10 49	10·0	04 03	1·8	22
		22 39	9·6	16 02	1·2		—	—	17 28	0·1		23 16	9·3	16 26	0·3	
23	F.	11 17	10·4	04 21	1·6	M.	00 22	10·0	05 45	0·8	M.	11 38	10·3	04 48	1·2	23
		23 40	9·9	16 48	0·5		12 42	10·9	18 10	*0·4		—	—	17 09	*0·4	
24	S.	—	—	05 09	0·9	Tu.	01 06	10·1	06 26	0·4	Tu.	00 04	9·6	05 26	0·5	24
		12 08	10·6	17 41	0·0		13 25	11·2	18 50	*0·6		12 22	10·5	17 48	*0·7	
25	S.	00 32	10·2	05 59	0·4	W.	01 45	10·3	07 05	0·2	W.	00 45	9·8	06 03	0·1	25
		12 58	10·9	18 29	*0·3		14 07	11·5	19 34	*0·3		13 05	10·6	18 30	*0·7	

The time used is STANDARD, or mean time of the meridian of Greenwich; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

ENGLAND, WEST COAST—LIVERPOOL, 1925.

Lat. 53° 25′ N. Long. 3° 00′ W.

Month Day.	Week Day.	SEPTEMBER. HIGH WATER. Time. H. M.	SEPTEMBER. HIGH WATER. Ht. F.	SEPTEMBER. LOW WATER. Time. H. M.	SEPTEMBER. LOW WATER. Ht. F.	Week Day.	OCTOBER. HIGH WATER. Time. H. M.	OCTOBER. HIGH WATER. Ht. F.	OCTOBER. LOW WATER. Time. H. M.	OCTOBER. LOW WATER. Ht. F.	Week Day.	NOVEMBER. HIGH WATER. Time. H. M.	NOVEMBER. HIGH WATER. Ht. F.	NOVEMBER. LOW WATER. Time. H. M.	NOVEMBER. LOW WATER. Ht. F.	Month Day.
1	Tu.	09 51	27·3	04 10	3·3	Th.	10 26	29·3	04 56	1·4	S.	11 28	29·6	06 01	1·1	1
		22 13	28·7	16 36	3·2		22 45	30·4	17 14	1·8		23 44	29·8	18 16	1·9	
2	W.	10 43	28·9	05 10	1·5	F.	11 11	30·1	05 45	0·3	M.	—	—	06 36	1·8	2
		23 02	30·2	17 32	1·8		23 28	30·9	18 00	1·2		12 05	29·0	18 51	2·4	
3	Th.	11 31	29·9	06 04	0·3	S.	11 52	30·3	06 28	0·2	Tu.	00 22	28·8	07 09	2·8	3
		23 49	31·0	18 22	0·9		—	—	18 41	1·1		12 40	28·2	19 24	3·3	
4	F.	—	—	06 52	*0·3	S.	00 09	30·8	07 06	0·6	W.	00 58	27·7	07 40	3·9	4
		12 15	30·3	19 06	0·8		12 31	29·7	19 18	1·6		13 14	27·2	19 57	4·3	
5	S.	00 32	31·1	07 34	*0·1	M.	00 47	29·9	07 40	1·7	Th.	01 34	26·3	08 11	5·3	5
		12 57	29·9	19 46	1·1		13 07	28·8	19 52	2·5		13 49	26·0	20 31	5·4	
6	S.	01 14	30·5	08 12	0·7	Tu.	01 24	28·6	08 12	3·1	F.	02 11	24·8	08 44	6·7	6
		13 37	28·9	20 23	2·1		13 43	27·3	20 26	3·8		14 28	24·8	21 10	6·7	
7	M.	01 55	29·3	08 47	2·2	W.	02 01	26·9	08 44	4·8	S.	02 54	23·3	09 24	8·0	7
		14 17	27·5	21 00	3·4		14 20	25·8	21 01	5·3		15 13	23·5	21 56	7·9	
8	Tu.	02 36	27·5	09 22	3·9	Th.	02 42	25·1	09 19	6·5	S.	03 47	21·8	10 14	9·2	8
		14 59	25·8	21 37	5·1		15 02	24·3	21 41	6·9		16 10	22·3	22 57	8·8	
9	W.	03 19	25·5	10 02	5·8	F.	03 29	23·2	10 02	8·2	M.	04 53	20·9	11 20	9·9	9
		15 44	24·0	22 21	6·8		15 53	22·7	22 34	8·4		17 22	21·8	—	—	
10	Th.	04 10	23·5	10 50	7·7	S.	04 29	21·5	10 59	9·6	Tu.	06 10	21·0	00 10	8·9	10
		16 40	22·4	23 18	8·3		16 59	21·5	23 44	9·3		18 35	22·3	12 37	9·8	
11	F.	05 15	21·8	11 53	9·0	S.	05 47	20·7	—	—	W.	07 19	22·1	01 23	8·2	11
		17 51	21·4	—	—		18 19	21·3	12 16	10·1		19 36	23·6	13 48	8·7	
12	S.	06 34	21·1	00 32	9·0	M.	07 07	21·1	01 05	9·1	Th.	08 15	23·8	02 26	6·8	12
		19 09	21·6	13 09	9·3		19 34	22·3	13 35	9·5		20 31	25·2	14 46	7·2	
13	S.	07 50	21·8	01 52	8·5	Tu.	08 12	22·6	02 17	7·8	F.	09 02	25·5	03 19	5·3	13
		20 17	22·8	14 23	8·6		20 29	24·0	14 41	8·1		21 16	26·8	15 37	5·6	
14	M.	08 50	23·1	03 00	7·3	W.	09 01	24·3	03 15	6·3	S.	09 43	27·1	04 05	3·8	14
		21 10	24·3	15 23	7·3		21 16	25·8	15 34	6·4		21 58	28·0	16 22	4·2	
15	Tu.	09 39	24·6	03 52	5·8	Th.	09 43	26·0	04 02	4·7	S.	10 22	28·3	04 48	2·7	15
		21 53	25·9	16 11	5·8		21 56	27·3	16 19	4·9		22 38	28·9	17 05	3·1	
16	W.	10 18	25·9	04 38	4·3	F.	10 20	27·3	04 44	3·3	M.	11 01	29·1	05 59	2·0	16
		22 31	27·2	16 53	4·7		22 33	28·4	16 59	3·8		23 18	29·5	17 47	2·3	
17	Th.	10 54	26·9	05 19	3·3	S.	10 55	28·3	05 23	2·4	Tu.	11 40	29·5	06 09	1·8	17
		23 06	28·1	17 31	3·8		23 08	29·1	17 37	2·9		23 59	29·4	18 29	2·1	
18	F.	11 27	27·6	05 55	2·6	S.	11 29	28·8	06 00	1·8	W.	—	—	06 49	1·9	18
		23 39	28·7	18 06	3·2		23 43	29·4	18 14	2·4		12 21	29·5	19 11	2·1	
19	S.	11 59	28·0	06 28	2·2	M.	—	—	06 35	1·8	Th.	00 42	29·0	07 30	2·4	19
		—	—	18 39	2·8		12 04	29·0	18 50	2·3		13 04	29·0	19 55	2·7	
20	S.	00 11	28·9	07 00	2·1	Tu.	00 19	29·3	07 10	2·0	F.	01 28	28·1	08 14	3·4	20
		12 30	28·2	19 12	2·8		12 40	28·8	19 26	2·5		13 52	28·0	20 42	3·5	
21	M.	00 44	28·8	07 32	2·3	W.	00 57	28·8	07 45	2·6	S.	02 20	26·8	09 05	4·7	21
		13 02	28·1	19 45	2·9		13 18	28·3	20 04	3·2		14 44	26·8	21 36	4·6	
22	Tu.	01 18	28·5	08 05	2·8	Th.	01 38	27·9	08 23	3·6	S.	03 22	25·3	10 02	6·2	22
		13 37	27·6	20 19	3·3		14 01	27·3	20 46	4·2		15 47	25·5	22 40	5·8	
23	W.	01 54	27·8	08 40	3·6	F.	02 25	26·5	09 08	5·1	M.	04 31	24·2	11 07	7·3	23
		14 16	26·8	20 58	4·3		14 50	26·0	21 37	5·4		16 57	24·7	23 51	6·3	
24	Th.	02 38	26·5	09 23	4·8	S.	03 24	24·9	10 05	6·6	Tu.	05 46	23·8	—	—	24
		15 04	25·6	21 46	5·5		15 54	24·6	22 42	6·6		18 14	24·7	12 22	7·5	
25	F.	03 32	24·9	10 14	6·4	S.	04 37	23·5	11 15	7·8	W.	07 01	24·3	01 08	5·9	25
		16 01	23·9	22 46	7·0		17 11	23·5	—	—		19 26	25·5	13 38	6·8	

The time used is STANDARD, or mean time of the meridian of Greenwich; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

WALES—HOLYHEAD. 1925.

Lat. 53° 19′ N. Long. 4° 37′ W.

Month Day.	Week Day.	MAY. HIGH WATER. Time. H. M.	MAY. HIGH WATER. Ht. F.	MAY. LOW WATER. Time. H. M.	MAY. LOW WATER. Ht. F.	Week Day.	JUNE. HIGH WATER. Time. H. M.	JUNE. HIGH WATER. Ht. F.	JUNE. LOW WATER. Time. H. M.	JUNE. LOW WATER. Ht. F.	Week Day.	JULY. HIGH WATER. Time. H. M.	JULY. HIGH WATER. Ht. F.	JULY. LOW WATER. Time. H. M.	JULY. LOW WATER. Ht. F.	Month Day.
1	F.	03 37	12·3	10 10	4·3	M.	05 07	12·7	11 39	3·8	W.	05 21	12·9	11 45	3·3	1
		16 30	11·9	22 33	5·6		18 01	12·4	—	—		18 10	12·8	—	—	
2	S.	04 58	12·1	11 28	4·4	Tu.	06 16	13·2	00 00	4·7	Th.	06 30	13·4	00 12	3·9	2
		17 51	12·2	23 58	5·4		19 00	13·3	12 44	3·1		19 11	13·7	12 47	2·8	
3	**S.**	06 12	12·5	—	—	W.	07 14	13·7	00 56	3·8	F.	07 33	14·0	01 10	3·1	3
		19 02	12·6	12 38	3·9		19 47	13·8	13 36	2·3		20 04	14·5	13 45	2·3	
4	M.	07 14	13·2	01 01	4·6	Th.	08 06	14·3	01 49	2·5	S.	08 28	14·6	02 05	1·9	4
		19 46	13·5	13 34	3·0		20 33	14·6	14 21	1·4		20 54	15·2	14 38	1·4	
5	Tu.	07 59	14·0	01 45	3·5	F.	08 53	15·0	02 33	1·8	**S.**	09 19	15·2	03 01	0·9	5
		20 26	14·4	14 18	2·1		21 16	15·2	15 02	0·7		21 43	16·0	15 29	0·7	
6	W.	08 40	15·1	02 21	2·6	S.	09 38	15·5	03 21	0·7	M.	10 10	15·7	03 52	0·0	6
		21 03	15·2	14 55	1·3		21 56	15·9	15 48	0·1		22 28	16·6	16 16	0·1	
7	Th.	09 20	15·4	02 57	1·7	**S.**	10 22	16·0	04 06	0·0	Tu.	11 03	16·0	04 39	*0·9	7
		21 40	15·4	15 30	0·4		22 40	16·8	16 28	*0·5		23 17	17·0	16 57	*0·6	
8	F.	09 57	16·0	03 38	0·6	M.	11 11	16·3	04 54	*0·5	W.	11 52	15·9	05 30	*1·3	8
		22 17	16·0	16 06	*0·2		23 26	16·9	17 12	*0·4		—	—	17 49	*0·5	
9	S.	10 39	16·4	04 22	*0·3	Tu.	—	—	05 45	*0·7	Th.	00 05	17·0	06 21	*0·9	9
		22 57	16·4	16 46	*0·5		12 01	15·8	17 59	*0·2		12 40	15·7	18 41	*0·1	
10	**S.**	11 20	16·2	05 09	*0·4	W.	00 14	16·7	06 34	*0·5	F.	00 55	16·6	07 11	*0·6	10
		23 39	16·5	17 26	*0·3		12 51	15·4	18 54	0·3		13 29	15·1	19 32	0·5	
11	M.	—	—	05 55	*0·1	Th.	01 06	16·0	07 29	0·1	S.	01 47	15·8	08 06	0·2	11
		12 06	15·9	18 11	0·1		13 47	14·6	19 49	1·4		14 24	14·0	20 26	1·5	
12	Tu.	00 22	16·2	06 42	0·3	F.	02 03	15·0	08 27	0·7	**S.**	02 40	14·9	08 58	1·0	12
		12 59	15·2	19 02	1·0		14 48	13·4	20 50	2·0		15 19	13·4	21 27	2·5	
13	W.	01 14	15·7	07 36	0·5	S.	03 06	14·3	09 28	1·1	M.	03 41	14·1	09 56	2·3	13
		13 58	14·2	19 59	1·8		15 54	12·8	22 01	2·6		16 22	12·7	22 35	3·4	
14	Th.	02 12	14·7	08 37	1·1	**S.**	04 15	13·8	10 35	2·0	Tu.	04 47	13·3	11 05	3·4	14
		15 12	13·2	21 02	2·7		17 06	12·6	23 10	3·3		17 31	12·5	23 44	4·0	
15	F.	03 19	13·9	09 42	1·9	M.	05 29	13·5	11 50	2·6	W.	05 57	13·1	—	—	15
		16 21	12·8	22 22	3·3		18 16	12·8	—	—		18 38	12·8	12 17	3·7	
16	S.	04 41	13·2	11 04	2·5	Tu.	06 36	13·5	00 21	3·2	Th.	07 04	13·2	00 51	3·9	16
		17 40	12·8	23 44	3·3		19 18	13·1	12 56	2·5		19 42	13·2	13 18	3·5	
17	**S.**	06 00	13·4	—	—	W.	07 37	13·7	01 20	2·9	F.	08 04	13·2	01 49	3·4	17
		18 54	13·2	12 24	2·3		20 10	13·5	13 51	2·3		20 33	13·2	14 15	3·1	
18	M.	07 08	14·0	00 54	2·8	Th.	08 27	14·0	02 11	2·4	S.	08 55	13·5	02 38	2·8	18
		19 49	13·9	13 27	2·5		20 56	13·8	14 36	2·0		21 13	13·5	15 00	3·0	
19	Tu.	08 02	14·5	01 44	2·0	F.	09 10	14·1	02 58	2·2	**S.**	09 35	13·7	03 25	2·4	19
		20 33	14·3	14 18	1·1		21 33	14·4	15 16	2·1		21 51	14·4	15 36	2·6	
20	W.	08 48	15·0	02 31	1·6	S.	09 47	14·5	03 40	2·0	M.	10 10	14·0	04 03	1·8	20
		21 12	14·7	14 59	0·8		22 07	14·8	15 54	1·9		22 23	14·8	16 10	2·1	
21	Th.	09 28	15·3	03 18	1·1	**S.**	10 26	14·5	04 19	1·8	Tu.	10 46	14·3	04 34	1·2	21
		21 49	15·0	15 37	0·6		22 40	14·9	16 28	1·9		22 56	15·0	16 39	1·7	
22	F.	10 05	15·3	03 56	0·9	M.	11 02	14·3	04 52	1·3	W.	11 20	14·6	05 06	1·2	22
		22 20	15·3	16 13	0·7		23 11	14·9	17 00	1·7		23 27	15·1	17 14	1·7	
23	S.	10 40	15·3	04 34	0·8	Tu.	11 38	14·3	05 26	1·2	Th.	11 52	14·5	05 38	1·1	23
		22 55	15·0	16 49	0·9		23 47	14·9	17 32	1·7		—	—	17 46	1·7	
24	**S.**	11 15	14·8	05 11	1·0	W.	—	—	06 00	1·6	F.	00 02	15·2	06 15	1·1	24
		23 30	14·7	17 19	1·0		12 13	14·2	18 06	2·1		12 26	14·2	18 21	1·8	
25	M.	11 53	14·4	05 49	1·1	Th.	00 23	14·7	06 38	1·9	S.	00 35	14·9	06 48	1·1	25
		—	—	17 55	1·8		12 48	13·8	18 46	2·6		12 58	13·9	18 54	1·8	

The time used is STANDARD, or mean time of the meridian of Greenwich ; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

IRELAND. EAST COAST—KINGSTOWN, 1925.

Lat. 53° 18′ N. Long. 6° 08′ W.

Month Day.	Week Day.	MAY. HIGH WATER. Time. H. M.	MAY. HIGH WATER. Ht. F.	MAY. LOW WATER. Time. H. M.	MAY. LOW WATER. Ht. F.	Week Day	JUNE. HIGH WATER. Time. H. M.	JUNE. HIGH WATER. Ht. F.	JUNE. LOW WATER. Time. H. M.	JUNE. LOW WATER. Ht. F.	Week Day.	JULY. HIGH WATER. Time. H. M.	JULY. HIGH WATER. Ht. F.	JULY. LOW WATER. Time. H. M.	JULY. LOW WATER. Ht. F.	Month Day.
1	F.	05 15	9·8	11 13	3·4	M.	06 34	9·5	—	—	W.	06 49	9·5	00 06	3·4	1
		18 05	8·9	23 44	4·5		19 24	9·1	12 43	2·8		19 29	9·3	12 51	2·4	
2	S.	06 26	9·2	—	—	Tu.	07 37	9·8	01 01	3·8	Th.	07 51	9·9	01 10	3·1	2
		19 15	8·9	12 27	3·2		20 20	9·6	13 44	2·2		20 29	9·9	13 47	2·2	
3	S.	07 34	9·3	00 53	4·1	W.	08 34	10·2	02 01	3·0	F.	08 49	10·3	02 08	2·4	3
		20 18	9·2	13 32	2·8		21 07	10·1	14 32	1·7		21 19	10·3	14 35	1·7	
4	M.	08 32	9·8	01 56	3·5	Th.	09 23	10·6	02 48	2·4	S.	09 43	10·7	03 01	1·7	4
		21 06	9·7	14 24	2·1		21 46	10·6	15 13	1·2		22 03	10·9	15 25	1·2	
5	Tu.	09 20	10·2	02 43	2·8	F.	10 06	11·0	03 25	1·5	S.	10 33	11·0	03 49	1·1	5
		21 45	10·0	15 10	1·7		22 25	11·1	15 49	0·6		22 45	11·4	16 09	0·7	
6	W.	09 58	10·6	03 24	2·3	S.	10 48	11·2	04 04	0·8	M.	11 22	11·1	04 38	0·2	6
		22 18	10·5	15 45	0·8		23 02	11·4	16 26	0·2		23 33	12·0	17 03	0·2	
7	Th.	10 33	11·1	03 57	1·4	S.	11 29	11·3	04 44	0·2	Tu.	—	—	05 26	*0·1	7
		22 46	10·8	16 18	0·5		23 46	11·8	17 07	0·0		12 10	11·6	17 42	0·1	
8	F.	11 04	11·5	04 28	0·7	M.	—	—	05 33	0·0	W.	00 23	12·4	03 18	0·0	8
		23 22	11·2	16 52	0·1		12 16	11·4	17 52	0·2		12 59	11·8	18 33	0·4	
9	S.	11 45	11·6	05 01	0·3	Tu.	00 32	12·2	06 26	0·2	Th.	01 17	12·3	07 07	0·1	9
		23 59	11·6	17 26	0·0		13 07	11·6	18 43	0·6		13 50	11·5	19 23	0·9	
10	S.	—	—	05 42	0·2	W.	01 28	12·3	07 15	0·6	F.	02 06	12·2	07 56	0·3	10
		12 31	11·6	18 07	0·2		14 04	11·4	19 36	1·2		14 43	11·0	20 14	1·3	
11	M.	00 46	11·7	06 31	0·3	Th.	02 27	12·0	03 11	0·9	S.	03 05	11·8	08 50	0·7	11
		13 20	11·6	18 55	0·7		15 06	10·9	20 35	1·7		15 43	10·6	21 08	2·0	
12	Tu.	01 41	11·8	07 23	0·8	F.	03 25	11·4	09 13	1·1	S.	04 02	11·4	09 50	1·4	12
		14 15	11·4	19 50	1·4		16 12	10·4	21 38	2·1		16 48	10·2	22 12	2·8	
13	W.	02 37	11·6	08 24	1·2	S.	04 33	10·9	10 26	1·3	M.	05 07	11·0	10 55	2·3	13
		15 14	10·8	20 54	1·9		17 24	10·0	22 56	2·7		17 55	9·9	23 22	3·3	
14	Th.	03 38	11·0	09 33	1·6	S.	05 40	10·5	11 39	1·7	Tu.	06 15	10·6	—	—	14
		16 26	10·3	22 03	2·6		18 38	9·6	—	—		19 04	9·7	12 04	2·7	
15	F.	04 48	10·8	10 50	1·9	M.	06 50	10·4	00 06	2·9	W.	07 26	10·2	00 37	3·3	15
		17 43	10·0	23 23	3·0		19 42	9·5	12 44	1·9		20 08	9·7	13 14	2·9	
16	S.	05 58	10·6	—	—	Tu.	08 01	10·2	01 12	2·9	Th.	08 34	10·1	01 45	3·3	16
		18 59	9·9	12 02	2·1		20 45	9·6	13 52	1·9		21 08	9·9	14 19	2·7	
17	S.	07 18	10·4	00 35	3·0	W.	08 58	10·3	02 15	2·4	F.	09 31	10·1	02 46	3·0	17
		20 07	10·0	13 16	2·0		21 36	9·8	14 49	1·7		21 58	10·1	15 13	2·5	
18	M.	08 20	10·8	01 41	3·0	Th.	09 46	10·0	03 10	1·9	S.	10 19	9·9	03 39	2·5	18
		21 03	10·3	14 13	1·6		22 16	10·1	15 37	1·4		22 37	10·2	15 58	2·7	
19	Tu.	09 16	10·9	02 33	2·3	F.	10 28	10·0	03 51	1·6	S.	10 56	10·0	04 20	1·9	19
		21 54	10·6	15 06	1·4		22 57	10·1	16 12	1·2		23 07	10·4	16 34	2·3	
20	W.	10 01	11·0	03 21	1·8	S.	11 09	10·0	04 32	1·2	M.	11 28	10·2	04 56	1·6	20
		22 32	10·8	15 46	1·0		23 28	10·3	16 48	1·3		23 38	10·7	17 05	2·1	
21	Th.	10 40	11·2	04 00	1·4	S.	11 42	10·1	05 08	1·2	Tu.	11 59	10·3	05 28	1·4	21
		23 07	11·1	16 23	1·1		23 59	10·4	17 21	1·5		—	—	17 35	1·8	
22	F.	11 18	11·4	04 37	1·3	M.	—	—	05 43	1·2	W.	00 13	10·6	05 58	1·3	22
		23 43	11·1	17 00	1·2		12 16	10·3	17 54	1·9		12 32	10·4	18 05	1·8	
23	S.	11 54	11·1	05 14	1·2	Tu.	00 30	10·5	06 16	1·2	Th.	00 46	10·8	06 29	1·1	23
		—	—	17 34	1·4		12 50	10·5	18 27	2·0		13 08	10·4	18 40	1·8	
24	S.	00 15	11·1	05 51	1·4	W.	01 05	10·6	06 51	1·4	F.	01 20	10·7	07 04	1·0	24
		12 32	11·0	18 11	1·6		13 26	10·2	19 02	2·2		13 41	10·1	19 13	2·1	
25	M.	00 50	11·0	06 31	1·5	Th.	01 41	10·6	07 27	1·7	S.	01 54	10·7	07 41	1·2	25
		13 11	10·6	18 47	2·1		14 05	10·0	19 38	2·7		14 15	10·0	19 50	2·0	

The time used is STANDARD, or mean time of the meridian of Greenwich; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

THE NETHERLANDS—FLUSHING, 1925.

Lat. 51° 27′ N. Long. 3° 36′ E.

Month Day.	Week Day.	SEPTEMBER. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day.	OCTOBER. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day.	NOVEMBER. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Month Day.
1	Tu.	11 55	13·2	06 05	*0·1	Th.	00 18	13·8	06 42	0·2	S.	01 23	13·6	07 45	*0/5	1
		—	—	18 38	*0·8		12 32	13·6	19 13	*0·8		13 40	13·4	20 17	*1·0	
2	W.	00 27	13·7	06 56	*0·3	F.	01 00	14·2	07 25	*0·2	M.	02 02	13·6	08 25	*0·5	2
		12 42	13·8	19 30	*1·2		13 13	14·0	19 58	*1·2		14 17	13·4	20 49	*0·9	
3	Th.	01 11	14·3	07 43	*0·4	S.	01 39	14·4	08 05	*0·4	Tu.	02 36	13·4	09 03	*0·6	3
		13 28	14·3	20 18	*1·5		13 52	14·1	20 40	*1·4		14 54	13·3	21 20	*0·6	
4	F.	01 58	14·6	08 24	*0·6	S.	02 19	14·2	08 43	*0·8	W.	03 11	13·1	09 43	*0·4	4
		14 12	14·4	21 01	*1·7		14 33	14·0	21 16	*1·5		15 27	13·2	21 55	*0·2	
5	S	02 45	14·5	09 08	*0·6	M.	03 00	13·8	09 23	*0·7	Th.	03 47	12·8	10 18	*0·3	5
		14 59	14·1	21 45	*1·6		15 13	13·5	21 52	*1·1		16 07	12·8	22 29	0·2	
6	S.	03 27	13·9	09 52	*0·4	Tu.	03 39	13·1	10 05	*0·1	F.	04 24	12·3	10 54	0·0	6
		15 42	13·5	22 29	*1·4		15 58	12·9	22 29	*0·5		16 49	12·4	23 05	0·7	
7	M.	04 07	13·4	10 34	*0·2	W.	04 16	12·6	10 46	0·1	S.	05 05	11·7	11 35	0·3	7
		16 25	13·0	23 07	*1·0		16 40	12·6	23 04	0·0		17 36	11·9	23 49	1·3	
8	Tu.	04 53	12·8	11 12	0·1	Th.	04 57	12·1	11 24	0·5	S.	05 54	11·1	—	—	8
		17 08	12·5	23 46	*0·4		17 21	12·0	23 44	0·6		18 37	11·2	12 20	0·8	
9	W.	05 34	12·0	11 54	0·6	F.	05 41	11·5	—	—	M.	06 59	10·2	00 40	1·9	9
		17 49	11·8	—	—		18 11	11·5	12 05	0·9		19 52	10·6	13 25	1·2	
10	Th.	06 21	11·3	00 23	0·2	S.	06 35	10·6	00 28	1·3	Tu.	08 19	9·9	02 02	2·2	10
		18 47	11·1	12 40	1·0		19 19	10·8	12 58	1·4		21 13	10·7	14 54	1·3	
11	F.	07 25	10·5	01 15	1·0	S.	07 53	10·0	01 35	1·9	W.	09 38	10·2	03 30	2·2	11
		20 05	10·5	13 48	1·4		20 47	10·5	14 19	1·6		22 25	11·2	16 13	1·2	
12	S.	08 48	10·0	02 27	1·5	M.	09 20	10·0	03 07	2·1	Th.	10 44	10·8	04 40	1·9	12
		21 33	10·3	15 14	1·6		22 07	10·9	15 54	1·4		23 15	11·8	17 17	0·9	
13	S.	10 14	10·2	03 59	1·6	Tu.	10 36	10·7	04 30	1·8	F.	11 26	11·6	05 34	1·5	13
		22 49	10·9	16 39	1·2		23 13	11·6	17 05	0·9		23 52	12·4	18 05	0·4	
14	M.	11 14	10·8	05 12	1·4	W.	11 28	11·4	05 24	1·3	S.	—	—	06 14	0·9	14
		23 43	11·5	17 44	0·7		23 57	12·1	17 55	0·3		12 03	12·2	18 43	*0·1	
15	Tu.	—	—	06 05	0·9	Th.	—	—	06 09	0·8	S.	00 27	13·0	06 49	0·4	15
		12 00	11·5	18 30	0·1		12 08	11·9	18 39	*0·1		12 39	12·9	19 17	*0·5	
16	W.	00 28	12·2	06 43	0·6	F.	00 34	12·7	06 48	0·5	M.	01 02	13·4	07 24	*0·2	16
		12 38	12·0	19 08	*0·4		12 40	12·4	19 16	*0·5		13 14	13·3	19 49	*0·8	
17	Th.	01 02	12·6	07 18	0·4	S.	01 02	13·0	07 23	0·3	Tu.	01 36	13·6	08 00	*0·6	17
		13 08	12·4	19 44	*0·8		13 09	12·9	19 50	*0·6		13 47	13·8	20 24	*0·9	
18	F.	01 33	12·9	07 49	0·0	S.	01 32	13·4	07 54	0·1	W.	02 13	13·8	08 41	*0·8	18
		13 38	12·8	20 18	*1·1		13 40	13·2	20 24	*0·7		14 24	14·0	21 01	*0·7	
19	S.	02 04	13·2	08 20	*0·1	M.	02 03	13·6	08 26	*0·2	Th.	02 48	13·8	09 25	*0·9	19
		14 10	13·1	20 53	*1·2		14 12	13·6	20 54	*0·9		15 04	14·0	21 39	*0·3	
20	S.	02 35	13·4	08 51	*0·3	Tu.	02 39	13·6	09 01	*0·4	F.	03 29	13·7	10 11	*0·6	20
		14 41	13·2	21 22	*1·3		14 51	13·6	21 29	*0·7		15 54	13·9	22 25	0·3	
21	M.	03 07	13·2	09 24	*0·2	W.	03 14	13·3	09 43	*0·1	S.	04 18	13·4	11 00	*0·3	21
		15 15	13·1	21 53	*1·0		15 29	13·3	22 03	*0·3		16 47	13·6	23 12	0·7	
22	Tu.	03 39	12·9	10 01	0·3	Th.	03 50	13·0	10 23	*0·1	S.	05 10	12·8	11 54	0·0	22
		15 51	12·9	22 31	*0·4		16 11	13·1	22 41	0·0		17 48	13·1	—	—	
23	W.	04 15	12·8	10 40	0·5	F.	04 32	12·7	11 09	0·2	M.	06 19	12·0	00 12	1·2	23
		16 30	12·7	23 10	*0·1		16 58	12·9	23 26	0·5		19 08	12·3	13 02	0·3	
24	Th.	04 58	12·3	11 24	0·6	S.	05 22	12·2	11 58	0·5	Tu	07 37	11·3	01 30	1·5	24
		17 13	12·4	23 52	0·3		17 57	12·4	—	—		20 37	11·8	14 26	0·4	
25	F.	05 44	11·8	—	—	S.	06 28	11·6	00 24	1·2	W.	09 04	11·0	03 01	1·5	25
		18 11	11·9	12 12	0·8		19 18	12·1	13 05	0·9		21 58	11·7	15 49	0·5	

The time used is STANDARD, or mean time of the meridian of 4° 53′ E.; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

FRANCE, WEST COAST—BREST, 1925.

Lat. 48° 23′ N. Long. 4° 29′ W.

Month Day.	Week Day.	OCTOBER. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day.	NOVEMBER. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day.	DECEMBER. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Month Day.
1	Tu.	03 03	24·4	09 22	4·3	S.	04 04	25·1	10 21	4·1	Tu.	04 19	24·0	10 36	5·4	1
		15 26	25·3	21 44	3·3		16 23	25·1	22 39	4·1		16 38	23·6	22 55	5·7	
2	W.	03 47	25·3	10 05	3·3	M.	04 40	24·9	10 57	4·4	W.	04 56	23·6	11 13	5·9	2
		16 08	25·9	22 25	2·8		16 59	24·4	23 15	4·8		17 14	23·1	23 31	6·4	
3	Th.	04 27	25·8	10 44	3·3	Tu.	05 16	24·1	11 33	5·1	Th.	05 32	23·1	11 48	6·4	3
		16 46	25·9	23 04	3·1		17 34	23·6	23 51	5·7		17 48	22·3	—	—	
4	F.	05 06	25·4	11 23	3·6	W.	05 52	23·3	—	—	F.	06 06	22·3	00 06	7·1	4
		17 24	25·3	23 41	3·9		18 09	22·5	12 09	6·2		18 25	21·5	12 24	7·2	
5	S.	05 41	24·6	11 59	4·6	Th.	06 28	22·1	00 27	7·1	S.	06 44	21·5	00 44	8·0	5
		18 00	24·1	—	—		18 47	21·2	12 47	7·5		19 03	20·5	13 04	8·2	
6	S.	06 19	23·3	00 19	5·1	F.	07 06	20·8	01 07	8·4	S.	07 24	20·5	01 24	9·0	6
		18 37	22·6	12 37	5·9		19 28	19·9	13 28	8·7		19 46	19·5	13 46	9·2	
7	M.	06 56	22·0	00 56	6·6	S.	07 50	19·5	01 50	9·7	M.	08 11	19·7	02 11	9·8	7
		19 14	21·2	13 15	7·4		20 17	18·7	14 16	10·0		20 40	18·9	14 38	10·0	
8	Tu	07 35	20·5	01 36	8·2	S.	08 48	18·7	02 45	10·7	Tu.	09 11	19·0	03 08	10·5	8
		19 58	19·5	13 59	9·0		21 25	17·9	15 19	10·8		21 47	18·5	15 41	10·3	
9	W.	08 23	19·0	02 23	9·8	M.	10 06	18·2	03 57	11·3	W.	10 22	19·0	04 16	10·7	9
		20 54	18·2	14 51	10·3		22 48	18·0	16 37	11·0		22 56	18·9	16 49	10·2	
10	Th.	09 31	18·0	03 25	11·0	Tu.	11 29	18·7	05 18	11·0	Th.	11 31	19·5	05 23	10·2	10
		22 14	17·6	16 04	11·2		—	—	17 56	10·3		—	—	17 56	9·5	
11	F.	11 02	18·0	04 47	11·5	W.	00 06	18·7	06 29	10·2	F.	00 04	19·5	06 26	9·4	11
		23 46	17·9	17 33	11·0		12 36	19·7	18 57	9·2		12 32	20·3	18 53	8·5	
12	S.	—	—	06 14	10·8	Th.	01 02	20·0	07 22	8·9	S.	00 58	20·7	07 18	8·2	12
		12 25	18·7	18 49	10·2		13 26	20·8	19 44	7·9		13 23	21·5	19 42	7·4	
13	S.	00 58	19·0	07 19	9·7	F.	01 47	21·3	08 05	7·5	S.	01 46	22·0	08 05	7·1	13
		13 25	19·9	19 44	8·9		14 07	22·1	20 24	6·6		14 08	22·6	20 27	6·2	
14	M	01 48	20·2	08 06	8·4	S.	02 26	22·6	08 43	6·2	M.	02 30	23·1	08 49	5·9	14
		14 09	21·2	20 26	7·5		14 44	23·3	21 01	5·4		14 52	23·6	21 11	5·3	
15	Tu.	02 28	21·5	08 45	7·2	S.	03 03	23·8	09 20	5·3	Tu.	03 14	24·3	09 32	4·9	15
		14 46	22·3	21 02	6·2		15 21	24·3	21 38	4·6		15 35	24·4	21 54	4·6	
16	W.	03 03	22·6	09 19	5·9	M.	03 39	24·6	09 56	4·4	W.	03 57	24·9	10 16	4·3	16
		15 19	23·5	21 35	5·3		15 58	24·8	22 15	4·1		16 19	24·9	22 38	4·3	
17	Th.	03 36	23·8	09 52	5·1	Tu.	04 17	25·1	10 35	4·1	Th.	04 42	25·3	11 01	4·1	17
		15 52	24·3	22 08	4·4		16 37	24·9	22 54	4·3		17 05	24·8	23 25	4·4	
18	F.	04 09	24·4	10 25	4·4	W.	04 56	25·1	11 14	4·3	F.	05 29	25·1	11 49	4·4	18
		16 26	24·8	22 42	4·1		17 17	24·6	23 36	4·6		17 52	24·4	—	—	
19	S.	04 42	24·8	10 58	4·1	Th.	05 38	24·6	11 58	4·9	S.	06 17	24·4	00 13	5·1	19
		16 59	24·8	23 16	4·3		18 00	23·8	—	—		18 42	23·5	12 39	5·3	
20	S.	05 17	24·6	11 34	4·4	F.	06 23	23·6	00 20	5·6	S.	07 07	23·5	01 05	6·1	20
		17 35	24·4	23 52	4·8		18 47	22·6	12 44	5·9		19 34	22·5	13 32	6·2	
21	M.	05 53	24·1	—	—	S.	07 14	22·6	01 11	6·9	M.	08 03	22·5	02 01	7·1	21
		18 13	23·6	12 12	5·3		19 42	21·3	13 39	7·2		20 34	21·3	14 31	7·1	
22	Tu.	06 34	23·1	00 32	5·7	S.	08 13	21·3	02 10	8·2	Tu.	09 06	21·5	03 03	8·0	22
		18 56	22·3	12 54	6·2		20 48	20·3	14 44	8·2		21 41	20·7	15 36	8·0	
23	W.	07 20	21·8	01 18	7·1	M.	09 26	20·5	03 20	9·0	W.	10 17	20·8	04 10	8·7	23
		19 47	21·0	13 45	7·7		22 09	20·0	15 59	8·9		22 53	20·3	16 45	8·4	
24	Th.	08 18	20·7	02 15	8·5	Tu.	10 49	20·7	04 39	9·2	Th.	11 28	20·8	05 20	8·9	24
		20 54	19·9	14 49	9·0		23 29	20·3	17 18	8·7		—	—	17 53	8·4	
25	F.	09 37	19·9	03 28	9·5	W.	—	—	05 55	8·7	F.	00 10	20·5	06 26	8·7	25
		22 22	19·4	16 11	9·5		12 05	21·2	18 29	7·9		12 34	21·0	18 56	8·0	

The time used is STANDARD, or mean time of the meridian of Greenwich ; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

UNITED STATES, ATLANTIC COAST—BOSTON, 1925.

Lat. 42° 22′ N. Long. 71° 03′ W.

Month Day	Week Day	SEPTEMBER. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day	OCTOBER. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day	NOVEMBER. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Month Day
1	Tu.	09 41	9·7	03 34	*1·2	Th.	10 18	10·4	04 10	*1·3	S.	11 33	10·7	05 25	*0·7	1
		22 02	11·1	15 52	*0·7		22 42	10·8	16 33	*1·1		—	—	17 53	*1·3	
2	W.	10 35	10·2	04 29	*1·6	F.	11 08	10·7	05 00	*1·4	M.	00 01	9·9	06 09	*0·5	2
		22 57	11·3	16 47	*1·1		23 32	10·8	17 24	*1·4		12 16	10·6	18 38	*1·1	
3	Th.	11 27	10·6	05 21	*1·8	S.	11 56	10·8	05 48	*1·3	Tu.	00 45	9·6	06 52	*0·1	3
		23 50	11·3	17 40	*1·4		—	—	18 13	*1·4		12 58	10·3	19 22	*0·9	
4	F.	—	—	06 11	*1·8	S.	00 22	10·6	06 34	*1·0	W.	01 29	9·2	07 36	0·3	4
		12 18	10·7	18 32	*1·5		12 42	10·7	19 01	*1·3		13 42	9·9	20 06	*0·5	
5	S.	00 41	11·0	06 59	*1·5	M.	01 09	10·2	07 20	*0·6	Th.	02 14	8·8	08 21	0·7	5
		13 08	10·7	19 23	*1·3		13 27	10·5	19 48	*1·0		14 26	9·5	20 53	*0·2	
6	S.	01 32	10·6	07 48	*1·1	Tu.	01 56	9·7	08 06	*0·1	F.	03 00	8·5	09 08	1·1	6
		13 57	10·5	20 14	*1·0		14 14	10·1	20 36	*0·5		15 13	9·1	21 49	0·2	
7	M.	02 22	10·0	08 36	*0·6	W.	02 43	9·1	08 53	0·4	S.	03 49	8·2	09 58	1·4	7
		14 45	10·1	21 05	*0·6		15 00	9·6	21 24	*0·1		16 02	8·8	22 30	0·5	
8	Tu.	03 13	9·4	09 26	0·0	Th.	03 32	8·6	09 42	0·9	S.	04 39	8·0	10 50	1·6	8
		15 36	9·7	21 58	*0·1		15 49	9·2	22 15	0·3		16 54	8·6	23 22	0·7	
9	W.	04 05	8·8	10 17	0·5	F.	04 23	8·2	10 33	1·3	M.	05 32	8·0	11 35	1·6	9
		16 27	9·3	22 52	0·3		16 41	8·8	23 08	0·6		17 48	8·5	—	—	
10	Th.	04 58	8·3	11 10	1·0	S.	05 17	8·0	11 27	1·5	Tu.	06 24	8·2	00 14	0·7	10
		17 21	9·0	23 47	0·6		17 35	8·6	—	—		18 42	8·5	12 39	1·3	
11	F.	05 54	8·0	—	—	S.	06 11	7·9	00 02	0·8	W.	07 15	8·5	01 06	0·7	11
		18 15	8·8	12 05	1·3		18 30	8·6	12 23	1·6		19 35	8·7	13 32	1·0	
12	S.	06 50	7·9	00 43	0·7	M.	07 04	8·1	00 57	0·8	Th.	08 04	8·9	01 55	0·5	12
		19 09	8·8	13 00	1·3		19 23	8·7	13 17	1·4		20 25	8·9	14 22	0·5	
13	S.	07 43	8·0	01 37	0·6	Tu.	07 55	8·4	01 48	0·6	F.	08 50	9·4	02 42	0·3	13
		20 01	8·9	13 53	1·2		20 14	9·0	14 09	1·0		21 14	9·2	15 09	0·0	
14	M.	08 33	8·3	02 28	0·4	W.	08 43	8·8	02 37	0·4	S.	09 34	9·9	03 28	0·0	14
		20 50	9·2	14 42	0·9		21 03	9·2	14 58	0·5		22 00	9·4	15 56	*0·5	
15	Tu.	09 20	8·6	03 15	0·2	Th.	09 28	9·2	03 22	0·1	S.	10 18	10·4	04 11	*0·2	15
		21 36	9·4	15 30	0·6		21 48	9·5	15 43	0·1		22 45	9·6	16 41	*1·0	
16	W.	10 03	8·9	03 59	0·0	F.	10 11	9·6	04 05	*0·1	M.	11 02	10·7	04 55	*0·4	16
		22 20	9·6	16 15	0·3		22 32	9·7	16 27	*0·3		23 31	9·7	17 26	*1·3	
17	Th.	10 44	9·2	04 41	*0·2	S.	10 51	10·0	04 46	*0·3	Tu.	11 46	11·0	05 40	*0·5	17
		23 02	9·8	16 56	0·0		23 14	9·8	17 09	*0·6		—	—	18 12	*1·5	
18	F.	11 24	9·5	05 20	*0·3	S.	11 31	10·3	05 26	*0·4	W.	00 17	9·8	06 25	*0·5	18
		23 43	9·9	17 37	*0·3		23 56	9·8	17 51	*0·9		12 32	11·1	19 00	*1·5	
19	S.	—	—	05 59	*0·4	M.	—	—	06 07	*0·4	Th.	01 06	9·7	07 13	*0·4	19
		12 03	9·7	18 18	*0·4		12 13	10·5	18 34	*1·0		13 21	11·0	19 50	*1·4	
20	S.	00 23	9·8	06 38	*0·3	Tu.	00 40	9·7	06 49	*0·3	F.	01 56	9·5	08 04	*0·2	20
		12 42	9·8	18 59	*0·5		12 55	10·6	19 19	*1·0		14 13	10·7	20 42	*1·2	
21	M.	01 05	9·7	07 18	*0·2	W.	01 25	9·6	07 34	*0·2	S.	02 51	9·3	09 00	0·1	21
		13 23	9·9	19 42	*0·5		13 40	10·5	20 07	*0·9		15 08	10·4	21 38	*0·9	
22	Tu.	01 47	9·5	08 00	0·0	Th.	02 13	9·3	08 22	0·1	S.	03 48	9·2	10 00	0·3	22
		14 06	9·9	20 28	*0·4		14 30	10·3	20 59	*0·7		16 08	9·9	22 37	*0·6	
23	W.	02 33	9·2	08 45	0·2	F.	03 07	9·1	09 15	0·4	M.	04 49	9·1	11 04	0·4	23
		14 52	9·9	21 18	*0·2		15 24	10·1	21 55	*0·4		17 11	9·6	23 38	*0·4	
24	Th.	03 24	8·9	09 35	0·4	S.	04 03	8·8	10 14	0·6	Tu.	05 52	9·2	—	—	24
		15 44	9·7	22 13	*0·1		16 24	9·8	22 54	*0·2		18 15	9·3	12 08	0·4	
25	F.	04 20	8·6	10 31	0·7	S.	05 05	8·7	11 18	0·7	W.	06 55	9·4	00 40	*0·3	25
		16 42	9·6	23 13	0·0		17 27	9·6	23 57	*0·2		19 19	9·3	13 13	0·1	

The time used is STANDARD, or mean time of the meridian of 75° W.; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*), when they should be *subtracted* from the depths.

CANADA, ATLANTIC COAST—ST. JOHN, N.B., 1925.

Lat. 45° 15′ N. Long. 66° 04′ W.

Month Day	Week Day	MAY. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day	JUNE. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day	JULY. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Month Day
1	F.	05 41	21·9	11 52	5 9	M.	06 54	22·2	00 38	5·9	W.	07 09	22 5	00 54	4·8	1
		18 16	21·3	—	—		19 25	23·0	13 04	5 2		19 34	23 9	13 15	4·5	
2	S.	06 40	21 8	00 21	6·7	Tu.	07 50	22·8	01 34	5·2	Th.	08 04	23·0	01 52	4·0	2
		19 14	21·8	12 51	5·8		20 16	23·8	13 58	4·6		20 26	24·8	14 11	4·0	
3	S.	07 37	22 3	01 22	6·2	W.	08 42	23·4	02 28	4·1	F.	08 57	23·7	02 47	3·0	3
		20 06	22·5	13 48	5·3		21 04	24·7	14 49	3·8		21 17	25·8	15 05	3·2	
4	M.	08 29	22·8	02 18	5·2	Th.	09 31	24·1	03 18	3·1	S.	09 49	24 6	03 40	2·2	4
		20 54	23·5	14 41	4·5		21 50	25·8	15 37	3·2		22 09	26 8	15 58	2·8	
5	Tu.	09 17	23·6	03 06	4·2	F.	10 18	24·9	04 06	2·3	S.	10 40	25·2	04 32	1·5	5
		21 39	24·4	15 28	3 8		22 35	26·8	16 24	2·8		23 00	27·5	16 51	2·3	
6	W.	10 02	24·3	03 50	3·3	S.	11 04	25·5	04 53	1·7	M.	11 31	25·9	05 25	1·0	6
		22 22	25·4	16 12	3·3		23 21	27·5	17 12	2·6		23 50	27 9	17 45	2·0	
7	Th.	10 45	25 0	04 33	2·6	S.	11 49	25·9	05 41	1·3	Tu.	—	—	06 18	0·7	7
		23 04	26·2	16 55	2·8		—	—	18 02	2·4		12 23	26·3	18 40	1·7	
8	F.	11 27	25·5	05 17	1·9	M.	00 08	27·8	06 31	1·0	W.	00 41	28·0	07 10	0·5	8
		23 46	26·9	17 39	2·6		12 36	26·1	18 53	2·3		13 16	26·4	19 36	1·6	
9	S.	—	—	06 03	1·5	Tu.	00 57	27·9	07 24	0·9	Th.	01 33	27 5	08 03	0·5	9
		12 10	25·7	18 25	2·5		13 26	26·0	19 46	2·3		14 10	26·1	20 31	1·6	
10	S.	00 29	27·2	06 51	1·3	W.	01 49	27·4	08 19	1·0	F.	02 27	26 7	08 57	0 9	10
		12 55	25·8	19 13	2·6		14 22	25·6	20 41	2·6		15 05	25 5	21 27	2·2	
11	M.	01 14	27 2	07 41	1·3	Th.	02 45	26·4	09 15	1·6	S.	03 25	25 6	09 52	1·8	11
		13 43	25·6	20 04	2·6		15 22	24·8	21 38	3·2		16 03	24·9	22 24	3·0	
12	Tu.	02 02	26 8	08 32	1·5	F.	03 45	25 3	10 12	2·5	S.	04 28	24·5	10 49	3·2	12
		14 35	24·9	20 57	3·2		16 26	24·3	22 39	4·0		17 06	24 3	23 23	4·2	
13	W.	02 56	25·8	09 25	2·2	S.	04 49	24·2	11 11	3·6	M.	05 34	23·4	11 48	4·4	13
		15 32	24 2	21 53	4·0		17 33	23 8	23 44	4·6		18 11	23·9	—	—	
14	Th	03 56	25·0	10 23	3·2	S.	05 56	23 6	—	—	Tu.	06 39	22·6	00 24	4·8	14
		16 36	23 6	22 54	4·8		18 40	23·7	12 14	4·4		19 12	23·6	12 49	5·2	
15	F.	05 03	24·0	11 28	4·1	M.	07 04	23·1	00 51	4·7	W.	07 40	22·2	01 27	4·9	15
		17 46	23·0	—	—		19 40	23·8	13 18	4·6		20 08	23·4	13 52	5·4	
16	S.	06 14	23 4	00 02	5 2	Tu.	08 07	23·0	01 57	4·4	Th.	08 37	22·1	02 29	4·8	16
		18 57	23·2	12 38	4·4		20 37	24·2	14 22	4·6		20 59	23·5	14 50	5·4	
17	S.	07 23	23·3	01 14	5 0	W.	09 04	23 0	02 56	4·0	F.	09 30	22·1	03 23	4·5	17
		20 04	23·8	13 49	4·4		21 27	24·5	15 18	4 6		21 46	23·7	15 40	5·4	
18	M.	08 25	23·5	02 22	4·2	Th.	09 54	23 3	03 46	3·8	S.	10 16	22·2	04 10	4·4	18
		21 02	24·4	14 52	3 9		22 12	24·6	16 07	4·8		22 29	23·9	16 23	5·5	
19	Tu.	09 22	24·0	03 19	3·5	F.	10 39	23 3	04 31	3·8	S.	10 56	22·6	04 51	4·4	19
		21 51	25 0	15 42	3·7		22 53	24·7	16 50	5 0		23 08	24·0	17 03	5·6	
20	W.	10 13	24·4	04 08	3·1	S.	11 20	23·1	05 14	3·9	M.	11 33	22·6	05 30	4·4	20
		22 35	25·3	16 27	3·8		23 32	24·6	17 30	5 2		23 44	24·1	17 42	5·5	
21	Th.	10 59	24·4	04 54	3·0	S.	11 58	23·0	05 56	4·0	Tu.	—	—	06 08	4·4	21
		23 16	25·4	17 11	4·0		—	—	18 09	5 4		12 09	22·8	18 22	5·4	
22	F.	11 40	24·1	05 38	3·1	M.	00 09	24·5	06 36	4·2	W.	00 19	24·2	06 46	4·2	22
		23 54	25·3	17 54	4·4		12 35	23 0	18 48	5·5		12 44	23·0	19 01	5·1	
23	S.	—	—	06 21	3·4	Tu.	00 46	24·5	07 15	4·2	Th.	00 55	24·3	07 23	4·0	23
		12 19	23·8	18 36	4·8		13 11	22·9	19 26	5·5		13 20	23·2	19 41	4·7	
24	S.	00 31	25 0	07 03	3·7	W.	01 21	24 3	07 53	4·2	F.	01 32	24·3	07 59	3·7	24
		12 57	23 4	19 16	5 2		13 48	22 9	20 05	5·4		13 58	23·4	20 21	4·5	
25	M.	01 07	24 6	07 43	4·0	Th.	01 58	24·0	08 30	4·1	S.	02 11	24·0	08 36	3·6	25
		13 35	23 1	19 55	5·4		14 27	22·8	20 45	5·3		14 39	23·5	21 02	4·4	

The time used is STANDARD, or mean time of the meridian of 60° W.; 00h. is midnight, 12h. Is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*), when they should be *subtracted* from the depths.

STRAITS SETTLEMENTS—SINGAPORE, 1925.

Lat. 1° 16′ N. Long. 103° 50′ E.

Month Day	Week Day	JANUARY. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day	FEBRUARY. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day	MARCH. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Month Day
1	Th.	03 02	8·6	08 39	4·3	S.	03 50	8·4	10 14	3·4	S.	02 10	8·6	08 19	2·1	1
		14 38	8·9	21 14	2·4		16 29	7·5	22 16	4·0		14 45	7·8	20 26	3·2	
2	F.	03 53	8·4	09 46	4·3	M.	04 39	8·2	11 33	3·4	M.	02 46	8·2	09 08	2·4	2
		15 48	8 2	22 17	3·2		17 49	7·0	23 15	4·7		15 39	7·0	21 03	4 0	
3	S.	04 53	8·3	11 02	4·2	Tu.	05 33	8·1	—	—	Tu.	03 28	7 9	10 16	2·7	3
		17 09	7·7	23 23	4·0		19 21	6·9	12 49	3·1		16 48	6·4	21 49	4·6	
4	S.	05 50	8·3	—	—	W.	06 29	8·0	00 26	5·1	W.	04 22	7·4	11 45	2·8	4
		18 35	7·5	12 24	3·8		20 35	7·1	13 56	2·7		18 46	6·2	23 05	5·1	
5	M.	06 46	8·4	00 30	4·3	Th.	07 27	8·1	01 39	5·3	Th.	05 28	7·2	—	—	5
		19 54	7·6	13 38	3·3		21 32	7·4	14 52	2 2		20 18	6·4	13 08	2 7	
6	Tu.	07 37	8·6	01 31	4·6	F.	08 22	8·4	02 40	5·1	F.	06 51	7·2	01 06	5·2	6
		21 02	7 8	14 32	2·7		22 14	7·8	15 36	1·8		21 13	6·9	14 19	2·3	
7	W.	08 22	8·9	02 26	4·7	S.	09 09	8·7	03 26	4·8	S.	07 58	7·5	02 16	4·9	7
		21 54	8·2	15 15	2·2		22 47	8·1	16 11	1·5		21 48	7·3	15 10	1·9	
8	Th.	09 03	9·1	03 14	4·8	S.	09 49	9·0	04 04	4·6	S.	08 48	7 9	03 08	4·4	8
		22 35	8·4	15 52	1·7		23 16	8·3	16 40	1·2		22 15	7·7	15 45	1·5	
9	F.	09 41	9·3	03 55	4·7	M.	10 26	9·3	04 36	4·2	M.	09 30	8·3	03 45	3·9	9
		23 09	8 5	16 26	1·4		23 43	8·5	17 08	0·9		22 40	8·0	16 14	1·1	
10	S.	10 17	9·5	04 30	4 6	Tu.	11 02	9·5	05 06	3·8	Tu.	10 08	8·8	04 17	3·3	10
		23 42	8 6	16 59	1·2		—	—	17 35	0·8		23 04	8·4	16 42	0·9	
11	S.	10 52	9 6	05 03	4·5	W.	00 09	8·7	05 35	3·4	W.	10 45	9·1	04 48	2·8	11
		—	—	17 31	1·1		11 37	9·6	18 03	0·8		23 29	8·7	17 09	0·7	
12	M.	00 14	8·7	05 35	4·4	Th.	00 35	8·9	06 06	3 0	Th.	11 22	9·3	05 19	2·2	12
		11 26	9·7	18 03	1·1		12 13	9·6	18 33	1·1		23 55	8·8	17 37	0·8	
13	Tu.	00 45	8 8	06 07	4·2	F.	01 02	8·9	06 40	2·8	F.	—	—	05 51	1·7	13
		11 59	9·7	18 36	1·2		12 51	9·4	19 06	1·4		12 00	9 3	18 07	1·1	
14	W.	01 15	8·8	06 41	4·1	S.	01 32	8·8	07 19	2·6	S.	00 23	8·8	06 25	1·4	14
		12 34	9·6	19 10	1·4		13 32	9·0	19 43	2·0		12 40	9·1	18 39	1·5	
15	Th.	01 46	8 8	07 19	4·0	S.	02 11	8·7	08 05	2·5	S.	00 54	8 8	07 03	1·2	15
		13 14	9·4	19 46	1·8		14 24	8·4	20 25	2 7		13 24	8·7	19 14	2·1	
16	F.	02 19	8·7	08 03	3·9	M.	02 55	8·4	09 02	2·6	M.	01 30	8·7	07 46	1·2	16
		14 00	8·9	20 26	2·3		15 29	7·6	21 14	3·6		14 15	8 0	19 54	2·9	
17	S.	02 56	8 6	08 54	3·9	Tu.	03 46	8·2	10 14	2·7	Tu.	02 11	8·3	08 39	1·5	17
		14 53	8·5	21 14	3·0		16 48	7·0	22 14	4·4		15 18	7·2	20 43	3·8	
18	S.	03 41	8·5	09 56	3 8	W.	04 48	7 9	11 44	2 6	W.	02 59	7 9	09 46	1·8	18
		16 01	7·9	22 14	3 8		18 46	6 8	23 41	5·1		16 45	6·6	21 46	4·5	
19	M.	04 38	8·3	11 11	3·7	Th.	06 02	7·9	—	—	Th.	04 09	7·4	11 22	1·9	19
		17 29	7·5	23 25	4 4		20 31	7·2	13 15	2·1		18 46	6·4	23 33	5·0	
20	Tu.	05 44	8·3	—	—	F.	07 22	8·2	01 38	5·2	F.	05 38	7·3	—	—	20
		19 11	7·5	12 33	3·3		21 32	7·8	14 35	1·4		20 22	6·9	12 59	1·7	
21	W.	06 53	8·5	00 44	4 8	S.	08 33	8·6	02 49	4 8	S.	07 13	7·5	01 38	4·8	21
		20 33	7·8	13 46	2·5		22 19	8·3	15 39	0·7		21 15	7·5	14 18	1·1	
22	Th.	07 56	8 8	02 01	5·0	S.	09 31	9·2	03 45	4·3	S.	08 28	8 2	02 52	4·1	22
		21 40	8·2	14 50	1·8		22 57	8 6	16 26	0·2		21 56	8·0	15 20	0·6	
23	F.	08 53	9·2	03 03	4·8	M.	10 19	9·6	04 27	3·7	M.	09 26	8·8	03 42	3·3	23
		22 33	8 7	15 45	1·0		23 31	8 8	17 03	0·1		22 29	8·4	16 08	0 3	
24	S.	09 44	9·7	03 53	4·6	Tu.	11 03	9·9	05 06	3 1	Tu.	10 15	9·2	04 21	2·5	24
		23 15	8·9	16 33	0·5		—	—	17 39	0·1		22 59	8·7	16 44	0·3	
25	S.	10 32	10·1	04 37	4·3	W.	00 03	8·9	05 44	2·6	W.	10 57	9·5	04 56	1·8	25
		23 54	9·2	17 16	0 3		11 46	10·0	18 14	0·5		23 28	8·8	17 17	0·5	

The time used is STANDARD, or mean time of the meridian of 105° E. ; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

NEW ZEALAND—WELLINGTON, 1925.

Lat. 41° 17′ S. Long. 174° 48′ E.

Month Day	Week Day	SEPTEMBER. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day	OCTOBER. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Week Day	NOVEMBER. HIGH WATER. Time. H. M.	Ht. F.	LOW WATER. Time. H. M.	Ht. F.	Month Day
1	Tu.	01 57	4·8	07 56	1·0	Th.	02 32	4·8	08 35	1·1	S.	04 08	4·8	10 32	1·3	1
		14 26	5·2	20 37	1·1		15 01	5·0	21 14	1·2		16 39	4·7	22 55	1·4	
2	W.	02 53	4·8	08 55	1·0	F.	03 28	4·8	09 36	1·2	M.	05 08	4·8	11 28	1·3	2
		15 21	5·2	21 34	1·1		15 57	4·9	22 14	1·2		17 40	4·6	23 48	1·4	
3	Th.	03 48	4·8	09 56	1·0	S.	04 27	4·8	10 42	1·1	Tu.	06 08	4·9	—	—	3
		16 18	5·1	22 32	1·1		16 57	4·8	23 14	1·2		18 41	4·7	12 22	1·2	
4	F.	04 47	4·8	10 59	1·0	S.	05 30	4·8	11 43	1·1	W.	07 05	4·9	00 40	1·3	4
		17 20	5·1	23 33	1·0		18 00	4·8	—	—		19 33	4·7	13 14	1·2	
5	S.	05 53	4·9	—	—	M.	06 31	4·9	00 10	1·2	Th.	07 52	5·0	01 32	1·3	5
		18 24	5·1	12 03	1·0		19 02	4·9	12 40	1·1		20 20	4·7	14 03	1·2	
6	S.	06 54	5·0	00 32	1·0	Tu.	07 28	5·0	01 04	1·1	F.	08 37	4·9	02 16	1·4	6
		19 21	5·1	13 00	0·9		19 57	4·9	13 34	1·0		21 05	4·6	14 49	1·2	
7	M.	07 50	5·1	01 27	1·0	W.	08 19	5·1	01 55	1·1	S.	09 21	4·9	03 00	1·4	7
		20 16	5·1	13 56	0·9		20 47	4·9	14 27	1·0		21 48	4 6	15 30	1·4	
8	Tu.	08 44	5·1	02 21	1·0	Th.	09 05	5·0	02 44	1·2	S.	10 01	4·7	03 40	1·6	8
		21 10	5·0	14 53	1·0		21 32	4·8	15 16	1·1		22 27	4·4	16 08	1·5	
9	W.	09 36	5·1	03 14	1·1	F.	09 52	5·0	03 32	1·3	M.	10 39	4·6	04 16	1·6	9
		22 01	4·9	15 48	1·1		22 18	4·6	16 05	1·2		23 03	4·4	16 44	1·6	
10	Th.	10 26	5·0	04 06	1·2	S.	10 39	4·8	04 19	1·4	Tu.	11 16	4·5	04 55	1·7	10
		22 50	4·7	16 40	1·2		23 05	4·5	16 52	1·4		23 42	4·4	17 24	1·7	
11	F.	11 14	4·9	04 58	1·3	S.	11 25	4·6	05 02	1·5	W.	—	—	05 38	1·8	11
		23 40	4·6	17 32	1·3		23 49	4·4	17 34	1·5		12 03	4·5	18 07	1·7	
12	S.	—	—	05 48	1·5	M.	—	—	05 41	1·7	Th.	00 27	4·4	06 22	1·7	12
		12 02	4·8	18 22	1·5		12 07	4·5	18 12	1·6		12 50	4·5	18 51	1·7	
13	S.	00 29	4·4	06 34	1·6	Tu.	00 28	4·3	06 18	1·7	F.	01 10	4·4	07 08	1·7	13
		12 46	4·6	19 08	1·6		12 46	4·5	18 51	1·7		13 32	4·5	19 35	1·6	
14	M.	01 11	4·3	07 17	1·7	W.	01 06	4·3	07 00	1·7	S.	01 52	4·5	07 57	1·6	14
		13 28	4·5	19 45	1·6		13 26	4·5	19 32	1·7		14 16	4·5	20 21	1·6	
15	Tu.	01 49	4·3	07 55	1·7	Th.	01 46	4·3	07 46	1·7	S.	02 38	4·6	08 52	1·6	15
		14 07	4·4	20 20	1·7		14 08	4·4	20 15	1·7		15 07	4·5	21 11	1·6	
16	W.	02 28	4·2	08 29	1·8	F.	02 29	4·3	08 35	1·7	M.	03 33	4·6	09 54	1·5	16
		14 48	4·4	20 58	1·7		14 54	4·4	21 01	1·7		16 08	4·5	22 15	1·5	
17	Th.	03 10	4·2	09 11	1·8	S.	03 16	4·3	09 26	1·7	Tu.	04 32	4·7	10 57	1·4	17
		15 33	4·4	21 46	1·8		15 45	4·4	21 53	1·7		17 09	4·6	23 13	1·4	
18	F.	03 56	4·1	10 02	1·8	S.	04 10	4·3	10 21	1·6	W.	05 34	4·8	11 57	1·3	18
		16 22	4·3	22 36	1·8		16 41	4·4	22 49	1·6		18 09	4·7	—	—	
19	S.	04 46	4·1	10 57	1·7	M.	05 09	4·4	11 20	1·5	Th.	06 34	5·0	00 11	1·3	19
		17 15	4·3	23 27	1·7		17 40	4·4	23 46	1·6		19 08	4·7	12 52	1·2	
20	S.	05 40	4·2	11 52	1·6	Tu.	06 08	4·6	—	—	F.	07 31	5·2	01 05	1·2	20
		18 11	4·4	—	—		18 38	4·6	12 16	1·4		20 00	4·8	13 42	1·0	
21	M.	06 36	4·3	00 18	1·7	W.	07 00	4·7	00 39	1·4	S.	08 21	5·2	01 55	1·1	21
		19 06	4·5	12 43	1·5		19 30	4·7	13 07	1·3		20 50	4·9	14 31	1·0	
22	Tu.	07 28	4·5	01 07	1·6	Th.	07 50	4·9	01 27	1·3	S.	09 10	5·3	02 43	1·1	22
		19 53	4·5	13 28	1·4		20 22	4·7	13 56	1·2		21 40	4·9	15 20	1·0	
23	W.	08 14	4·6	01 50	1·5	F.	08 39	5·0	02 13	1·2	M.	10 01	5·2	03 33	1·2	23
		20 38	4·6	14 13	1·3		21 12	4·7	14 45	1·1		22 30	4·8	16 10	1·1	
24	Th.	08 59	4·8	02 32	1·4	S.	09 28	5·1	03 00	1·2	Tu.	10 53	5·1	04 26	1·2	24
		21 25	4·6	15 01	1·3		22 00	4·7	15 34	1·1		23 20	4·8	17 03	1·2	
25	F.	09 45	4·9	03 17	1·3	S.	10 18	5·1	03 48	1·2	W.	11 43	5·0	05 22	1·3	25
		22 13	4·6	15 51	1·3		22 48	4·7	16 24	1·2		—	—	17 59	1·3	

The time used is STANDARD, or mean time of the meridian of 172° 30′ E. ; 00h. is midnight, 12h. is noon. The heights are referred to the datum of the largest scale Admiralty chart of the place and should be *added* to the depths given on the chart unless preceded by an asterisk (*) when they should be *subtracted* from the depths.

TABLE IV.—(*b*) MOON'S PHASES, DECLINATION, ETC.

JANUARY.		FEBRUARY.		MARCH.		APRIL.		MAY.		JUNE.	
Month Day.	Moon.	Month Day.	Moon.	Month Day.	Moon.	Month Day.	Moon.	Month Day.	Moon.	Month Day.	Moon.
1	☽ E	4	A.	2	☽	1	☽ N. A.	1	☽	2	E
8	A	5	N.	4	A. N.	8	E.	5	E.	6	○
9	N.	8	○	10	○	9	○	8	○	8	P. S.
10	○	12	E.	12	E.	13	P.	11	P.	13	☾
16	E.	16	☾	17	☾	14	S.	12	S.	14	E.
17	☾	19	S.	18	S.	15	☾	15	☾	21	●
23	S.P.	20	P.	20	P.	21	E.	18	E.	22	N.
24	●	23	●	24	●	23	●	22	●	23	A.
29	E.	25	E.	25	E	28	N.	25	N.	29	☽ E.
31	☽					29	A.	26	A.		
								30	☽		

P. = Perigee, A = Apogee; ● = New Moon, ☽ = First Quarter, ○ = Full Moon,
☾ = Last Quarter; N. = Declination maximum north, E. = Moon on equator.
S. = Declination maximum south.

TABLE IV.—(*b*) MOON'S PHASES. DECLINATION, ETC.

JULY.		AUGUST.		SEPTEMBER.		OCTOBER.		NOVEMBER.		DECEMBER.	
Month Day.	Moon.	Month Day.	Moon.	Month Day.	Moon.	Month Day.	Moon.	Month Day.	Moon.	Month Day.	Moon.
6	○ P. S.	2	S.	1	P.	2	○ E.	5	N.	3	N.
12	☽ E.	3	P.	2	○	9	☾ N.	7	A.	5	A.
19	N.	4	○	4	E.	11	A.	8	☾	8	☾
20	● A.	8	E	10	☾	16	E.	13	E.	10	E.
27	E.	11	☾	12	N.	17	●	16	●	15	●
28	☾	15	N.	13	A	23	S.	19	S.P.	17	S.P.
		16	A.	18	●	24	☽	23	☽	22	☽
		19	●	19	E.	25	P.	26	E.	23	E.
		23	E.	25	☽	29	E.	30	○	30	○ N.
		27	☽	26	S.	31	○				
		29	S.	29	P.						

P. = Perigee, A. = Apogee; ● = New Moon, ☽ = First Quarter, ○ = Full Moon,
☾ = Last Quarter; N. = Declination maximum north, E. = Moon on equator.
S. = Declination maximum south.

PART II.

TIDAL CONSTANTS AND TIDAL DIFFERENCES.

The names of Standard ports predicted in Part I. are printed in SMALL CAPITALS.

Unless otherwise stated :—

1. The High and Low water intervals are given for Moon's Transit 0h. or 12h., and are therefore the H.W.F. & C. and L.W.F. & C.

2. Heights of Mean High Water Springs (M.H.W.S.) and Mean High Water Neaps (M.H.W.N.) are given above the datum of the largest scale Admiralty chart, and are therefore the Mean Spring Rise and Mean Neap Rise.

3. The height of Mean Tide Level (M.T.L.) is given above the datum of the largest scale Admiralty chart.

4. The Differences in Time, applied according to sign to the predicted times at the Standard port, give the times of high and low water at the Secondary port in Standard or Local Time as given in the Time Difference columns.

5. The Difference in height, applied according to sign to the predicted heights at the Standard port, give the heights of high and low water at the Secondary port above the datum of the largest scale Admiralty chart of the Secondary port. Where the height of low water, resulting from the application of the tidal difference to the height of low water at the Standard port, is preceded by a minus sign (—) it indicates that the height is *below* datum at the Secondary port.

TIDAL CONSTANTS.

No.	Place.	Position.			Interval.		Height of		
		Latitude.	Longitude.		H.W.	L.W.	M.H. W.S.	M.H. W.N.	M.T. L.
			Arc.	Time.					
	ENGLAND, SOUTH COAST—	° ′	° ′	H. M.	H. M.	H. M.	F.	F.	F.
86	Shoreham,	50 49 N.	0 14 W.	0 01 W.	11 26	18 10	18·0	13·6	9·2
89	Brighton,	50 49	0 09 W.	0 01 W.	11 15	—	19·7	16·0	—
90	Newhaven,	50 47	0 03 E.	0 00	11 14	—	19·1	15·0	10·0
91	Beachy Head,	50 44	0 14	0 01 E.	11 20	—	20·0	15·0	—
92	Hastings,	50 51	0 35	0 02	10 53	—	25·1	18·7	12·7
93	Rye Bay,	50 56	0 45	0 03	11 20	—	23·2	18·5	—
96	Dungeness,	50 54	0 58	0 04	10 45	—	21·7	19·0	—
97	Folkestone,	51 05	1 11	0 05	11 07	—	20·0	16·5	—
98	DOVER,	51 07	1 19	0 05	11 12	18 39	18·2	14·2	9·0
	ENGLAND, EAST COAST—								
100	Deal,	51 13	1 25	0 06	11 15	—	16·0	12·5	—
101	Ramsgate,	51 20	1 25	0 06	11 44	—	15·7	12·5	8·0
103	Margate,	51 23	1 23	0 06	11 45	—	15·5	13·0	—
104	Kentish Knock,	51 39	1 37	0 06	11 47	—	12·8	—	—
105	Long Sand,	51 45	1 33	0 06	11 50	—	12·8	—	—
106	Pansand Hole,	51 27	1 10	0 05	0 00	—	15·5	13·0	—
107	The Nore,	51 29	0 49	0 03	0 30	—	16·6	13·5	—
	SCOTLAND, EAST COAST—								
250	Eyemouth,	55 52	2 05	0 08	2 15	—	15·0	11·0	—
251	Dunbar,	56 00	2 31	0 10	2 08	—	16·7	13·3	9·6
252	Cockenzie,	55 58	2 57	0 12	2 16	—	15·8	13·0	—
253	LEITH,	55 59	3 10	0 13	2 28	8 33	18·0	14·3	10·0
254	Granton,	55 59	3 13	0 13	2 31	—	17·9	14·5	10·0
	River Forth—								
256	ROSYTH,	56 01	3 25	0 14	2 37	8 27	17·5	13·9	9·7
257	Grangemouth,	56 02	3 39	0 15	2 55	8 03	16·9	13·3	8·5
258	Alloa,	56 07	3 47	0 15	3 18	—	17·5	15·0	—
259	Stirling,	56 07	3 56	0 16	3 52	—	*7·5	*1·8	—
260	Burntisland,	56 03	3 14	0 13	2 34	—	18·1	14·6	10·2
261	Methil,	56 11	3 00	0 12	2 20	—	18·0	13·5	—
262	Fife Ness,	56 17	2 35	0 10	2 10	—	15·0	12·0	—
	River Tay—								
265	Bar,	56 27	2 38	0 11	2 06	—	16·0	13·5	—
266	Broughty Ferry,	56 27	2 52	0 11	2 22	—	15·5	12·5	—
267	Dundee,	56 27	2 58	0 12	2 32	—	15·5	12·5	8·2
268	Perth,	56 24	3 27	0 14	3 35	—	*9·5	—	—
270	Arbroath,	56 33	2 35	0 10	1 35	—	14·0	11·0	—
271	Montrose,	56 42	2 28	0 10	2 17	—	15·5	12·5	8·5
272	Stonehaven,	56 58	2 12	0 09	1 10	—	14·0	11·0	7·0
273	Aberdeen,	57 09	2 05	0 08	1 00	—	12·8	9·	6·4
288	Inverness,	57 29	4 14	0 17	12 18	—	14·0	11·3	7·9

* Range of tide.

TIDAL DIFFERENCES.

No.	Standard Port.	Time of H.W.		Time of L.W.		Height of H.W.		Height of L.W.		Ratio of Ranges.
		Sp.	Np.	Sp.	Np.	Sp.	Np.	Sp.	Np.	
		H. M.	H. M.	H. M.	H. M.	F.	F.	F.	F.	
86	Dover,	+0 20	+0 05	−0 24	−0 39	−0·2	−0·6	+1·5	−0·1	0·92
89	—	—	—	—	—	—	—	—	—	—
90	Dover,	+0 07	—	—	—	+0·9	+0·8	+1·2	+1·2	0·98
91	—	—	—	—	—	—	—	—	—	—
92	Dover,	−0 16	−0 17	—	—	+6·9	+4·5	+1·4	+2·0	1·28
93	,,	+0 10	+0 18	—	—	+5·1	+4·3	—	—	—
96	—	—	—	—	—	—	—	—	—	—
97	—	—	—	—	—	—	—	—	—	—
98	Dover,	0 00	0 00	0 00	0 00	0·0	0·0	0·0	0·0	1·00
100	—	—	—	—	—	—	—	—	—	—
101	Dover,	+0 31	+0 23	—	—	−2·5	−1·7	+0·9	−0·4	0·84
103	—	—	—	—	—	—	—	—	—	—
104	Sheerness,	−1 21	—	—	—	−4·3	—	—	—	—
105	,,	−1 17	—	—	—	−4·3	—	—	—	—
106	—	—	—	—	—	—	—	—	—	—
107	Sheerness,	−0 10	—	—	—	−0·5	−0·5	—	—	—
250	—	—	—	—	—	—	—	—	—	—
251	Leith,	−0 23	−0 10	—	—	−1·3	−1·0	+0·4	+0·2	0·88
252	—	—	—	—	—	—	—	—	—	—
253	Leith,	0 00	0 00	0 00	0 00	0·0	0·0	0·0	0·0	1·00
254	,,	+0 03	−0 02	—	—	−0·1	+0·2	0·0	−0·2	1·00
256	Rosyth,	0 00	0 00	0 00	0 00	0·0	0·0	0·0	0·0	1·00
257	,,	+0 19	+0 21	−0 23	−0 48	−0·6	−0·7	−2·0	−1·8	1·11
258	—	—	—	—	—	—	—	—	—	—
259	—	—	—	—	—	—	—	—	—	—
260	Leith,	+0 06	+0 11	—	—	+0·1	+0·3	0·0	−0·1	1·02
261	—	—	—	—	—	—	—	—	—	—
262	—	—	—	—	—	—	—	—	—	—
265	—	—	—	—	—	—	—	—	—	—
266	—	—	—	—	—	—	—	—	—	—
267	Leith,	+0 03	+0 01	—	—	−2·4	−1·8	−1·1	−2·3	0·97
268	—	—	—	—	—	—	—	—	—	—
270	—	—	—	—	—	—	—	—	—	—
271	—	—	—	—	—	—	—	—	—	—
272	—	—	—	—	—	—	—	—	—	—
273	Leith,	−1 33	—	—	—	−5·1	−5·1	−1·9	−2·6	0·76
288	Invergordon,	+0 14	+0 07	—	—	+0·4	+0·6	−0·1	−0·6	1·10

TIDAL CONSTANTS.

No.	Place.	Position.			Interval.		Height of		
		Latitude.	Longitude.		H.W.	L.W.	M.H. W.S.	M.H. W.N.	M.T. L.
			Arc.	Time.					
		° ′	° ′	H. M.	H. M.	H. M.	F.	F.	F
	SCOTLAND, EAST COAST—								
	Cromarty Firth—								
290	Cromarty,	57 41 N.	4 02 W.	0 16 W.	11 52	17 56	13·6	11·0	8·1
291	INVERGORDON,	57 41	4 10	0 17	12 04	18 10	13·6	10·7	7·8
292	Dingwall,	57 36	4 25	0 18	11 39	—	13·0	9·8	—
293	Portmahomack,	57 50	3 50	0 15	0 07	—	14·0	9·0	—
	Dornoch Firth—								
294	Meikle Ferry,	57 51	4 08	0 17	0 35	—	15·2	9·5	—
295	Bonar Bridge,	57 53	4 21	0 17	0 34	—	*6·5	*3·5	—
296	Golspie,	57 58	3 58	0 16	11 55	—	13·5	10·0	—
297	Wick,	58 26	3 05	0 12	11 22	—	10·2	8·1	5·5
298	Duncansby Head,	58 39	3 03	0 12	10 14	—	10·0	7·0	—
	ENGLAND, WEST COAST—								
	Solway Firth—								
560	Port Carlisle,	54 57 N.	3 10 W.	0 13 W.	12 10	—	20·0	14·0	—
561	Silloth,	54 52	3 24	0 14	11 40	—	25·8	21·5	13·5
562	Maryport,	54 43	3 30	0 14	11 26	—	24·5	20·2	13·2
563	Workington,	54 39	3 34	0 14	11 20	—	25·8	20·0	—
564	Harrington,	54 36	3 34	0 14	11 15	—	25·0	19·0	—
565	Whitehaven,	54 33	3 36	0 14	11 14	—	25·8	20·7	14·2
566	Tarn Point,	54 17	3 25	0 14	11 22	—	25·5	20·5	13·7
	Morecambe Bay—								
570	Barrow Docks,	54 06	3 12	0 13	11 11	18 14	28·9	22·7	15·2
571	Morecambe,	54 04	2 52	0 11	11 26	—	28·3	22·6	14·7
572	Glasson Dock,	54 00	2 51	0 11	11 16	—	30·3	23·9	—
573	Lancaster,	54 03	2 48	0 11	11 16	—	30·2	23·8	—
574	Wyre Lighthouse,	53 57	3 02	0 12	11 11	—	28·5	21·9	14·8
580	Ribble Lighthouse,	53 44	3 01	0 12	10 51	—	26·7	19·7	13·9
581	Preston,	53 45	2 43	0 11	11 20	—	17·0	10·0	—
582	Formby Point,	53 34	3 07	0 12	10 35	—	27·2	21·2	—
583	Liverpool N.W.Light-vessel	53 31	3 30	0 14	11 00	—	26·2	21·2	—
584	LIVERPOOL,	53 25	3 00	0 12	11 17	18 06	28·7	22·8	15·2
585	Hilbre Island,	53 23	3 13	0 13	11 00	—	27·8	22·0	14·2
586	Chester,	53 12	2 54	0 12	0 16	—	*10·0	—	—
	WALES—								
590	Point of Air,	53 21	3 19	0 13	10 54	—	25·0	19·0	—
	Menai Strait—								
591	Trwyn Du,	53 19	4 02	0 16	10 21	—	22·8	17·6	11·7
592	Beaumaris,	53 16	4 05	0 16	10 30	—	23·2	16·4	11·0
593	Menai Bridge,	53 13	4 09	0 17	10 24	—	22·8	15·9	10·8
594	Pwllfanog,	53 13	4 12	0 17	9 40	—	19·5	12·7	9·2
595	Dinorwic,	53 11	4 13	0 17	9 35	—	16·2	13·3	9·1
596	Carnarvon,	53 08	4 16	0 17	9 30	—	14·8	11·9	8·2
597	Belan Point,	53 08	4 20	0 17	9 24	—	13·2	10·3	6·9
598	Llanddwyn Island,	53 08	4 25	0 18	9 16	—	13·3	10·6	6·9
605	Amlwch,	53 25	4 20	0 17	10 15	—	20·0	15·5	—
606	HOLYHEAD,	53 19	4 37	0 18	10 08	16 13	16·0	12·5	8·3
607	Porth Dinlleyn,	52 56	4 33	0 18	8 40	—	12·6	9·8	6·9

* Range of tide.

TIDAL DIFFERENCES.

No.	Standard Port.	Time of H.W.		Time of L.W.		Height of H.W.		Height of L.W.		Ratio of Ranges.
		Sp.	Np.	Sp.	Np.	Sp.	Np.	Sp.	Np.	
		H. M.	H. M.	H. M.	H. M.	F.	F.	F.	F.	
			Greenwich Mean Time.							
290	Invergordon, .	−0 13	−0 04	−0 15	−0 36	0·0	+0·3	+0·4	+0·5	0·97
291	,, .	0 00	0 00	0 00	0 00	0·0	0·0	0·0	0·0	1·00
292	—	—	—	—	—	—	—	—	—	—
293	—	—	—	—	—	—	—	—	—	—
294	—	—	—	—	—	—	—	—	—	—
295	—	—	—	—	—	—	—	—	—	—
296	—	—	—	—	—	—	—	—	—	—
297	Invergordon, .	−0 47	−1 07	—	—	−3·4	−2·7	−1·4	−1·8	0·83
298	—	—	—	—	—	—	—	—	—	—
560	—	—	—	—	—	—	—	—	—	—
561	Liverpool, . .	+0 25	—	—	—	−2·9	−1·4	−0·9	−1·8	0·96
562	,, . .	+0 11	—	—	—	−4·2	−2·7	0·0	−1·3	0·87
563	—	—	—	—	—	—	—	—	—	—
564	—	—	—	—	—	—	—	—	—	—
565	Liverpool, . .	−0 01	+0 05	—	—	−3·0	−2·2	+0·8	+0·4	0·85
566	,, . .	+0 07	+0 06	—	—	−3·2	−2·4	+0·8	−1·1	0·96
570	,, . .	−0 04	−0 10	+0 10	+0 10	+0·1	−0·1	+0·3	−0·1	1·00
571	,, . .	+0 08	+0 11	—	—	−0·4	−0·3	−0·6	−0·9	1·02
572	,, . .	−0 02	—	—	—	+1·6	+1·0	+7·2	+1·6	—
573	,, . .	−0 02	—	—	—	+1·5	+0·9	+14·4	+8·4	—
574	,, . .	−0 06	−0 04	—	—	−0·2	−0·9	+0·2	−0·3	0·98
580	,, . .	−0 26	—	—	—	−2·0	−3·1	−0·6	+0·8	0·88
581	—	—	—	—	—	—	—	—	—	—
582	—	—	—	—	—	—	—	—	—	—
583	—	—	—	—	—	—	—	—	—	—
584	Liverpool, . .	0 00	0 00	0 00	0 0 00	0·0	0·0	0·0	0·0	1·00
585	,, . .	−0 16	—	—	—	−0·9	−0·8	−0·4	−0·7	0·99
586	—	—	—	—	—	—	—	—	—	—
590	—	—	—	—	—	—	—	—	—	—
591	Holyhead, . .	+0 11	—	—	—	+6·8	+5·0	+0·5	+1·1	1·44
592	,, . .	+0 20	+0 18	—	—	+7·2	+3·9	−0·3	+0·1	1·48
593	,, . .	+0 15	—	—	—	+6·8	+3·4	−0·3	+0·1	1·45
594	,, . .	−0 29	—	—	—	+3·5	+0·1	−0·3	+0·1	1·16
595	,, . .	−0 34	—	—	—	+0·2	+0·8	+1·1	+1·2	0·94
596	,, . .	−0 39	−0 27	—	—	−1·2	−0·6	+0·6	+0·8	0·86
597	,, . .	−0 45	—	—	—	−2·8	−2·2	−0·3	−0·2	0·81
598	,, . .	−0 52	—	—	—	−2·7	−1·9	+0·3	−1·2	0·84
605	—	—	—	—	—	—	—	—	—	—
606	Holyhead, . .	0 00	0 00	0 00	0 00	0·0	0·0	0·0	0·0	1·00
607	,, . .	−1 28	—	—	—	−3·4	−2·7	+0·7	−0·4	0·73

TIDAL CONSTANTS.

No.	Place.	Position.			Interval.		Height of		
		Latitude.	Longitude.		H.W.	L.W.	M.H. W.S.	M.H. W.N.	M.T. L.
			Arc.	Time.					
	WALES—*Contd.*—								
	Cardigan Bay—	° ′	° ′	H. M.	H. M.	H. M.	F.	F.	F.
610	Bardsey,	52 46 N.	4 47 W.	0 19 W.	7 40	—	13·7	10·6	7·7
611	St. Tudwall Road,	52 49	4 28	0 18	7 44	—	13·6	10·4	6·9
612	Pwllheli,	52 53	4 24	0 18	7 51	—	14·0	10·6	7·1
613	Port Madoc Bar,	52 53	4 10	0 17	7 35	—	14·3	10·9	7·3
614	Sarn Badrig,	52 42	4 20	0 17	7 30	—	13·0	—	—
615	Barmouth,	52 43	4 03	0 16	7 46	—	14·9	11·0	7·5
616	Sarn y bwch,	52 35	4 14	0 17	7 40	—	14·0	—	—
625	Aberystwith,	52 24	4 05	0 16	7 37	—	14·1	10·2	7·2
626	New Quay,	52 13	4 21	0 17	7 30	—	14·1	9·8	7·1
627	Cardigan,	52 07	4 42	0 19	7 01	—	12·0	9·0	—
628	Newport,	52 02	4 53	0 20	7 00	—	12·0	9·0	—
629	Fishguard,	52 00	4 58	0 20	6 58	—	12·4	8·9	—
	IRELAND, EAST COAST—								
	Dundalk—								
740	Pile Light,	53 58	6 17	0 25	10 56	—	16·0	14·2	9·4
741	Soldier's Point,	50 00	6 21	0 25	11 23	—	15·0	11·1	8·0
	Lough Carlingford—								
745	Cranfield Point,	54 01	6 03	0 24	11 00	—	15·2	12·2	8·3
746	Warren Point,	54 06	6 15	0 25	11 10	—	15·4	12·8	8·3
747	Victoria Lock,	54 08	6 18	0 25	11 43	—	16·0	12·2	—
748	Newcastle,	54 12	5 53	0 24	11 04	—	17·4	14·7	10·2
749	Ardglass,	54 15	5 36	0 22	11 00	—	16·0	12·0	—
	THE NETHERLANDS—								
	East Schelde—								
1601	Westkapelle,	51 31 N.	3 27 E.	0 14 E.	1 15	7 53	11·2	8·7	5·0
1602	Veere,	51 32	3 40	0 15	2 02	8 01	10·1	8·2	4·6
1603	Zierikzee,	51 37	3 55	0 16	2 52	8 21	9·6	8·2	4·5
1604	Wemeldinge,	51 31	3 58	0 16	3 15	8 52	11·1	9·5	5·2
1605	Bergen op Zoom,	51 30	4 18	0 17	3 30	—	12·6	11·6	6·0
	West Schelde—								
1611	Wielingen,	51 23	3 11	0 13	0 49	7 33	12·9	10·1	5·8
1612	VLISSINGEN (Flushing),	51 27	3 36	0 14	1 16	7 48	13·3	10·5	6·0
1613	Borssele,	51 25	3 44	0 15	1 49	8 17	13·0	10·6	5·9
1614	Neuzen,	51 20	3 50	0 15	1 53	8 26	13·8	11·4	6·3
1615	Hansweert,	51 25	4 00	0 16	2 41	9 01	14·4	12·0	6·6
1616	Bat,	51 24	4 13	0 17	3 10	9 35	15·3	12·7	7·0
	BELGIUM—								
	Schelde River—								
1621	Liefkenshoek,	51 18	4 17	0 17	3 25	—	16·5	14·0	8·3
1622	Anvers (Antwerp),	51 14	4 25	0 18	3 45	10 34	16·5	14·0	8·3
1623	Zeebrugge,	51 20	3 12	0 13	0 53	7 16	14·2	11·7	7·0
1624	Ostende,	51 14	2 55	0 12	0 32	7 07	14·6	11·9	7·0
1625	Nieuport,	51 10	2 44	0 11	0 18	—	16·0	13·0	—

TIDAL DIFFERENCES.

No.	Standard Port.	Time of H.W.		Time of L.W.		Height of H.W.		Height of L.W.		Ratio of Ranges.
		Sp.	Np.	Sp.	Np.	Sp.	Np.	Sp.	Np.	
		H. M.	H. M	H. M.	H. M.	F.	F.	F.	F.	
		Greenwich Mean Time.								
610	Holyhead,	−2 27	—	—	—	−2·3	−1·9	+1·6	0·0	0·76
611	,,	−2 24	—	—	—	−2·4	−2·1	0·0	−0·9	0·84
612	,,	−2 17	−2 11	—	—	−2·0	−1·9	+0·1	−1·2	0·88
613	,,	−2 34	—	—	—	−1·7	−1·6	+0·3	−1·1	0·89
614	—	—	—	—	—	—	—	—	—	—
615	Holyhead,	−2 24	—	—	—	−1·1	−1·5	+0·3	−0·8	0·91
616	—	—	—	—	—	—	—	—	—	—
625	Holyhead,	−2 33	−2 27	—	—	−1·9	−2·3	+0·3	−0·6	0·84
626	,,	−2 39	—	—	—	−1·9	−2·7	0·0	−0·1	0·81
627	—	—	—	—	—	—	—	—	—	—
628	—	—	—	—	—	—	—	—	—	—
629	Holyhead,	−3 08	−3 12	—	—	−3·6	−3·6	—	—	0·73
740	Kingstown,	−0 13	−0 10	—	—	+4·3	+4·4	+1·9	+1·2	1·32
741	,,	+0 14	−0 01	—	—	+3·3	+1·3	+1·7	+0·1	1·16
745	,,	−0 10	—	—	—	—	—	—	—	—
746	,,	+0 01	−0 16	—	—	+3·7	+3·0	0·0	+0·8	1·33
747	,,	+0 34	—	—	—	—	—	—	—	—
748	,,	−0 06	−0 08	—	—	+5·7	+4·9	+1·9	+2·5	1·35
749	—	—	—	—	—	—	—	—	—	—
		Standard Time (20m. *fast on G.M.T.*).								
1601	Vlissingen,	−0 01	+0 04	+0 05	+0 16	−2·1	−1·8	+0·2	−0·2	0·84
1602	,,	+0 45	+0 38	+0 12	+0 22	−3·2	−2·3	+0·4	−0·4	0·77
1603	,,	+1 34	+1 14	+0 31	+0 45	−3·7	−2·3	+0·5	−0·5	0·75
1604	,,	+1 57	+1 41	+1 02	+1 03	−2·2	−1·0	+0·4	−0·4	0·86
1605	,,	+2 11	—	—	—	−0·7	+1·1	+0·5	−0·5	1·03
1611	,,	−0 26	−0 23	−0 14	−0 20	−0·4	−0·4	0·0	0·0	0·96
1612	,,	0 00	0 00	0 00	0 00	0·0	0·0	0·0	0·0	1·00
1613	,,	+0 32	+0 28	+0 28	+0 25	−0·3	+0·1	0·0	0·0	1·00
1614	,,	+0 36	+0 32	+0 37	+0 31	+0·5	+0·9	0·0	0·0	1·07
1615	,,	+1 23	+1 08	+1 11	+1 01	+1·1	+1·5	−0·2	+0·2	1·12
1616	,,	+1 52	+1 43	+1 45	+1 29	+2·0	+2·2	−0·1	+0·1	1·19
		Greenwich Mean Time.								
1621	,,	+1 46	—	—	—	+3·2	+3·5	+1·0	+1·5	1·18
1622	,,	+2 05	—	+2 22	—	+3·2	+3·5	+1·0	+1·5	1·18
1623	,,	−0 42	−0 33	−0 51	−0 35	+0·9	+1·2	+1·2	+0·9	1·00
1624	,,	−1 02	−0 54	−0 59	−0 46	+1·3	+1·4	+0·5	+1·1	1·06
1625	,,	−1 15	—	—	—	+2·7	+2·5	—	—	—

TIDAL CONSTANTS.

No.	Place.	Position.			Interval.		Height of		
		Latitude.	Longitude.		H.W.	L.W.	M.H. W.S.	M.H. W.N.	M.T. L.
			Arc.	Time.					
	FRANCE, NORTH COAST—	° ′	° ′	H. M.	H. M.	H. M.	F.	F.	F.
1721	Plougrescan,	48 51 N.	3 13 W.	0 13 W.	5 22	11 43	31·8	24·6	18·2
1722	Tréguier,	48 47	3 13	0 13	5 28	11 43	32·3	24·4	17·9
1723	Ploumanach,	48 50	3 29	0 14	5 22	11 33	28·9	23·0	16·5
1724	Pointe de Dourvin,	48 44	3 34	0 14	5 01	—	28·2	22·0	15·8
1725	Ile Louet,	48 40	3 54	0 16	4 53	11 15	28·2	22·0	15·8
1726	Morlaix,	48 35	3 50	0 15	4 53	—	30·5	—	—
1731	Roscoff,	48 43	3 58	0 16	4 52	11 10	28·5	22·0	15·9
1732	Ile de Bas,	48 44	4 00	0 16	4 47	11 16	27·6	22·3	15·8
1733	L'Abervrach,	48 37	4 36	0 18	4 34	10 47	25·3	20·0	14·4
1734	L'Aberbenoit,	48 35	4 38	0 19	4 05	10 36	26·2	21·0	15·2
1735	Porsal,	48 33	4 42	0 19	4 09	—	26·2	20·7	15·2
1736	Ile d'Ouessant,	48 27	5 06	0 20	3 38	10 07	24·9	19·7	14·8
	FRANCE, WEST COAST—								
1741	Ile de Molène,	48 24 N.	4 58 W.	0 20 W.	3 56	10 19	25·3	20·0	15·0
1742	Le Conquet,	48 22	4 47	0 19	3 42	10 05	24·3	19·4	14·6
1743	BREST,	48 23	4 29	0 18	3 46	10 04	24·6	19·4	14·6
1744	Camaret,	48 16	4 36	0 18	3 38	9 54	23·6	18·4	14·1
1745	Douarnenez,	48 06	4 20	0 17	3 34	9 47	23·3	18·4	14·0
1746	Ile de Sein,	48 02	4 52	0 19	3 33	9 40	22·0	17·1	13·2
1747	Audierne,	48 01	4 33	0 18	3 19	9 31	19·0	15·4	11·8
1748	Penmarch,	47 48	4 20	0 17	3 19	9 29	15·7	12·1	8·9
1749	Loctudy,	47 50	4 10	0 17	3 26	9 30	16·1	12·5	9·0
1750	Benodet,	47 53	4 07	0 16	3 26	9 36	16·1	12·5	9·0
1751	Concarneau,	47 52	3 54	0 16	3 25	9 30	16·1	12·5	9·0
1752	Ile de Penfret,	47 44	3 57	0 16	3 22	9 32	16·1	12·5	9·0
1756	Port Louis,	47 42	3 21	0 13	3 25	9 37	16·4	12·8	9·2
1757	L'Orient,	47 45	3 21	0 13	3 30	9 42	16·4	12·8	9·2
1758	*Belle Ile*, Le Palais,	47 21	3 09	0 13	3 23	9 30	16·7	13·1	9·4
1759	Port Harliguen,	47 29	3 06	0 12	3 40	9 42	17·3	13·3	9·7
1760	La Trinité.	47 35	3 01	0 12	3 38	9 43	17·8	13·7	10·0

TIDAL DIFFERENCES.

No.	Standard Port.	Time of H.W.		Time of L.W.		Height of H.W.		Height of L.W.		Ratio of Ranges.
		Sp.	Np.	Sp.	Np.	Sp.	Np.	Sp.	Np.	
		H. M.	H. M.	H. M.	H. M.	F.	F.	F.	F.	
		Greenwich Mean Time.								
1721	Brest, . .	+1 28	+1 06	+1 31	+1 11	+7·2	+5·2	0·0	+2·0	1·32
1722	,, . .	+1 34	+1 09	+1 31	+1 14	+7·7	+5·0	−1·1	+1·5	1·41
1723	,, . .	+1 28	+1 00	+1 21	+0 59	+4·3	+3·6	−0·9	+0·4	1·28
1724	,, . .	+1 11	—	—	—	+3·6	+2·6	−1·3	0·0	1 25
1725	,, . .	+1 08	+0 51	+1 12	+0 54	+3·6	+2·6	−1·3	0·0	1·25
1726	,, . .	+1 08	—	—	—	+5·9	—	—	—	—
1731	,, . .	+1 03	+0 44	+1 04	+0 53	+3·9	+2·6	−1·3	0·0	1·26
1732	,, . .	+0 58	—	+1 10	—	+3·0	+2·9	−1·3	0·0	1·24
1733	,, . .	+0 48	+0 35	+0 43	+0 25	+0·7	+0·6	−1·3	−1·0	1·12
1734	,, . .	+0 20	+0 23	+0 33	+0 33	+1·6	+1·6	−0·7	0·0	1·14
1735	,, . .	—	—	—	—	+1·6	+1·3	−0·7	0·0	1·12
1736	,, . .	−0 08	0 00	+0 03	+0 03	+0·3	+0·3	0·0	0·0	1·02
1741	,, . .	+0 10	+0 07	+0 15	+0 13	+0·7	+0·6	+0·3	0·0	1·07
1742	,, . .	−0 05	−0 05	0 00	0 00	−0·3	0·0	+0·3	0·0	0·95
1743	,, . .	0 00	0 00	0 00	0 00	0·0	0·0	0·0	0·0	1·00
1744	,, . .	−0 08	−0 08	−0 10	−0 10	−1·0	−1·0	0·0	0·0	0·90
1745	,, . .	−0 12	−0 15	−0 17	−0 15	−1·3	−1·0	0·0	−0·3	0·90
1746	,, . .	−0 12	−0 15	−0 23	−0 13	−2·6	−2·3	0·0	−0·6	0·85
1747	,, . .	−0 29	−0 27	−0 35	−0 29	−5·6	−4·0	0·0	−1·6	0·76
1748	,, . .	−0 26	−0 20	−0 34	−0 27	−8·9	−7·3	−2·6	−4·2	0·68
1749	,, . .	−0 20	−0 16	−0 34	−0 20	−8·5	−6·9	−2·6	−4·2	0·71
1750	,, . .	−0 19	−0 12	−0 27	−0 25	−8·5	−6·9	−2·6	−4·2	0·71
1751	,, . .	−0 20	−0 14	−0 35	−0 19	−8·5	−6·9	−2·6	−4·2	0·71
1752	,, . .	−0 25	−0 15	−0 31	−0 24	−8·5	−6·9	−2·6	−4·2	0·71
1756	,, . .	−0 22	−0 19	−0 27	−0 22	−8·2	−6·6	−2·6	−4·2	0·73
1757	,, . .	−0 17	−0 12	−0 32	−0 20	−8·2	−6·6	−2·6	−4·2	0·73
1758	,, . .	−0 28	−0 22	−0 39	−0 20	−7·9	−6·3	−2·6	−3·9	0·74
1759	,, . .	−0 12	−0 05	−0 28	−0 14	−7·3	−6·1	−2·5	−3·7	0·75
1760	,, . .	−0 14	−0 14	−0 27	−0 10	−6·8	−5·7	−2·4	−3·5	0·78

TABLE I.—*Age of Tide.*

Age.	Place.
Days. 0	West coast of America between lat. 20° N. and lat. 20° S.; Pacific Islands; East Coast of Australia.
½	West Coast of America, except between lat. 20° N. and lat. 20° S.; Australia, except East Coast; East Coast of Asia south of lat. 30° N.; Formosa; Japan; Islands in the Indian Ocean.
1	East Coast of Asia north of lat. 30° N.; South Coast of Asia; East Coast of Africa; Madagascar; West Coast of Africa south of lat. 30° N.; East Coast of America between lat. 40° S. and lat. 50° N.
1½	East Coast of South America south of lat. 40° S.; East Coast of North America north of lat. 50° N.; Iceland; West Coasts of Africa and Europe from lat. 30° N. to North Cape in Norway, including the English Channel, Ireland, and West Coasts of England and Scotland.
2	East Coast of Scotland and England north of lat. 52° N.; North Coast of Europe.
2½	East Coast of England south of lat. 52° N.; Coasts of Belgium, Holland, Germany, and Denmark.

INDEX TO PART II.

	No.
Aberdeen,	273
Aberystwith,	625
Air, Point of,	590
Alloa,	258
Amlwch,	605
Antwerp,	1622
Anvers,	1622
Arbroath,	270
Ardglass,	749
Audierne,	1747
Bardsey,	610
Barmouth,	615
Barrow Docks,	570
Bas, Ile de,	1732
Bat,	1616
Beachy Head,	91
Beaumaris,	592
Belan Point,	597
Belle Ile,	1758
Benodet,	1750
Bergen op Zoom,	1605
Bonar Bridge,	295
Borssele,	1613
Brest,	1743
Brighton,	89
Broughty Ferry,	266
Burntisland,	260
Camaret,	1744
Cardigan,	627
„ Bay,	616-629
Carlingford, Lough,	745-747
Carlisle, Port,	560
Carnarvon,	596
Chester,	586
Cockenzie,	252
Concarneau,	1751
Conquet, Le,	1742
Cranfield Point,	745
Cromarty,	290
„ Firth,	290-292
Deal,	100
Dingwall,	292
Dinorwic,	595
Dornoch Firth,	294, 295
Douarnenez,	1745
Dourvin, Point de,	1724
Dover,	98
Dunbar,	251
Duncansby Head,	298
Dundalk,	740, 741
Dundee,	267
Dungeness,	96
Eyemouth,	250
Fife Ness,	262
Fishguard,	629
Folkestone,	97
Formby Point,	582
Glasson Dock,	572
Golspie,	296
Grangemouth,	257
Granton,	254
Hansweert,	1615
Harliguen, Port,	1759
Harrington,	564
Hastings,	92
Hilbre Island,	585
Holyhead,	606
Invergordon,	291
Inverness,	288
Kentish Knock,	104
L'Aberbenoit,	1734
L'Abervrach,	1733
Lancaster,	573
Leith,	253
Liefkenshoek,	1621
Liverpool, N.W. light vessel,	583
Liverpool,	584
Llanddwyn Island,	598
Loctudy,	1749
Long Sand,	105
L'Orient,	1757
Louet, Ile,	1725
Louis, Port,	1756
Madoc, Port,	613
Margate,	103
Maryport,	562
Meikle Ferry,	294

	No.
Menai Bridge,	593
,, Strait,	591-598
Methil,	261
Molène, Ile de,	1741
Montrose,	271
Morecambe,	571
,, Bay,	570-574
Morlaix,	1726
Newcastle, Ireland,	748
Newhaven,	90
Newport, Cardigan Bay,	628
New Quay, Cardigan Bay,	626
Neuzen,	1614
Nieuport,	1625
Nore, The,	107
Ostende,	1624
Ouessant, Ile de,	1736
Pansand Hole,	106
Penfret, Ile de,	1752
Penmarch,	1748
Perth,	268
Plougrescan,	1721
Ploumanach,	1723
Porsal,	1735
Porth Dinlleyn,	607
Portmahomac,	293
Preston,	581
Pwllfanog,	594
Pwllheli,	612
Ramsgate,	101
Ribble Lighthouse,	580
Roscoff,	1731
Rosyth,	256
Rye Bay,	93
Saint Tudwall Road,	611
Sarn Badrig,	614
Sarn y bwch,	616
Schelde River,	1601-1622
Sein, Ile de,	1746
Shoreham,	86
Silloth,	561
Soldier's Point,	741
Solway Firth,	560-565
Stirling,	259
Stonehaven,	272
Tarn Point,	566
Tay River,	265-268
Tréguier,	1722
Trinité, La,	1760
Trwyn du,	591
Veere,	1602
Victoria Lock,	747
Vlissingen,	1612
Warren Point,	746
Wemeldinge,	1604
Westkapelle,	1601
Whitehaven,	565
Wick,	297
Wielingen,	1611
Workington,	563
Wyre Lighthouse,	574
Zeebrugge,	1623
Zierikzee,	1603

TEXT-BOOKS to be USED in the EXAMINATIONS.

Officially Recommended by the B.O.T.

For Naval Architecture—Ship Construction and Calculations. By GEORGE NICOL. 23/- nett (per post 23/6).

For Stability—Ship Stability and Trim. By PERCY HILLHOUSE. 12/6 nett (per post 13/-.)

Officially Recommended by the Departmental Committee on Examinations of Mates & Masters.

Ship's Business—Shipmaster's Handbook to the Merchant Shipping Acts. By SANFORD D. COLE, Barrister-at-Law. 12/6 nett (per post 13/-.)

Cargo Work—Stowage: The Properties and Stowage of Cargoes. By CAPT. R. E. THOMAS. 42/- nett (per post 42/9.)

Miscellaneous—From Slip to Sea: A Complete Chronological Account of Ship Yard Practice. 10/6 nett (per post 11/-.)

Other Specially Recommended Books.

Navigation—Nicholls's Concise Guide for Mates and Masters. 16/- nett (per post 16/6.)

The St. Hilaire Method in Practice. By CAPT. W. E. SOMMERVILLE. 5/- nett (per post 5/4.)

Modern Chartwork. By W. K. STEWART and J. W. STEPHEN. 8/6 nett (per post 8/11.)

Seamanship—Nicholls's Seamanship. 12/6 nett (per post 13/-.)

Brown's Rule of the Road Manual. 2/6 nett (per post 3/-.)

Jutsum's Rule of the Road Cards. 3/6 nett (per post 3/9.)

Ship's Business—Shipmaster's Business Companion. By J. W. ANDERSON. 5/6 nett (per post 5/9.)

Signalling—Brown's Signalling and Allied Signal Manual. 3/6 nett (per post 3/10.)

Jutsum's Commercial Code of Signal Cards. 3/6 nett (per post 3/9.)

Stability—Ship Stability and Other Calculations. By GEORGE NICOL, M.I NA. 10/6 nett (per post 11/-.)

Miscellaneous.—Deviation and the Deviascope. By CAPT. C. H. BROWN. 8/6 nett (per post 9/-.)

Meteorology for Masters and Mates. By CAPT. C. H. BROWN. 3/6 nett (per post 3/8.)

The Lifeboat (for Lifeboat Certificate). 6d. nett (per post 7d.)

Horner's Easy Astronomy. 3/6 nett (per post 3/9.)

Nautical Star Chart. 2/6 nett (per post 2/8.)

Brown's Nautical Almanac (for General Knowledge). 3/- nett (per post 3/6.)

Simple Surgery at Sea. By W. J. S. CAMERON, M.B., Ch. B. 3/6 nett (per post 3/9.)

BROWN, SON & FERGUSON, Limited,

Nautical Publishers since 1860,

52-58 Darnley Street, - - GLASGOW, S.1.